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ENGINEERING AND DESIGN

EXECUTIVE SUMMARY

U.S. DEPARTMENT OF COMMERCE
MARITIME ADMINISTRATION
IN COOPERATION WITH
LEVINGSTON SHIPBUILDING COMPANY
AND
ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES

IHI

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PREFACE

This document is a summary of a report on Engineering & Design resulting form the Shipbuilding Technology Transfer Program performed by Livingston Shipbuilding Company under a cost-sharing contract with the U.S. Maritime Administration.

This summary provides a condensation of the findings and conclusions of Livingston's study of the design engineering practices currently in use in the shipyards of Ishikawajima-Harima Heavy Industries CO., Ltd., (IHI), of Japan. Livingston gratefully acknowledges the generous assistance of the IHI consulting personnel and of all the IHI personnel in Japan who made this study possible.

For details concerning the Technology Transfer Program or of the information contained herein, please refer to the full Final Report on this subject.

EXECUTIVE SUMMARY

PURPOSE AND SCOPE

The purpose of this study was to analyze the Japanese (IHI) concept of design engineering and its application in the actual working environment in IHI shipyards. As in the many other areas of study within the Technology Transfer Program (TTP) the objective of the study was to define possible beneficial and cost-saving elements or methodologies which could be instituted in Livingston and in other medium size shipyards in the United States.

In this examination of the IHI design engineering concepts and applications, particular attention is given to the flow of work beginning with the Basic Design through the Functional Design to the Detail Design.

ORGANIZATION

This report comprises two volumes: I - Findings and Conclusions and II - Appendices. This volume consists of six sections:

- Section 1 - Introduction
- Section 2 - Design Initiation
- Section 3 - Shipyard Design & Engineering
- Section 4 - Computer Aided Design
- Section 5 - Numerical Control Steel Fabrication
- Section 6 - Livingston System and Application of IHI Technology

Sections 2, 3, 4 and 5 comprise an account of the findings and an analysis of the concepts employed and the actual functioning of these concepts in IHI.

Several appendices (source data) are also included as Volume II of this report. These appendices are listed below:

Appendix A - Brief Explanation of IHICS

Appendix B - IHICS - Actual Output Examples

Appendix C - Summary of IHI SHELL

Appendix D - LODACS - Ship Frame Data Processing System

Appendix E - SPECS - Ship's Preliminary and Exact Calculation System

Appendix F - SPECS - Actual Output Example

Appendix G - CADS - Piping Design System

Appendix H - IHI Report on Computer-Aided Design System

Appendix I - IHI Report on Numerical Control Steel Fabrication

Appendix J - LSCo Study and Comparison of SPADES vs. IHI System

Appendix K - LSCo Final Report - Sub-task 2.1 Computer-Aided Design Systems

Appendix L - LSCo Final Report - Sub-task 2.2 Numerical Control Steel Fabrication

Appendix M - IHI Working Flow and Scheme for Hull Structure Design

Appendix N - Explanation of IHI's Design Flow (Piping)

Appendix O - Z PLATE - Gneral Purpose Program of Plane Stress Analysis by Finite Element Method and its application

Appendix P - Z VIBRA - Matrix Method of Vibrational Analysis of Framed Structures and its application

DESIGN INITIATION

The design and engineering function at IHI is responsible for ship design and the dissemination of design and construction information to Production. This design and engineering activity is accomplished by a "top-down" refinement procedure which begins with a conceptual ship design determined through research and design teams at the IHI Head

Office. This conceptual design is refined to become the basic design. Figure 1-1 describes the flow as the conceptual design is transformed from concept to basic guidelines, to functional diagrammatic design and finally to detail design.

BASIC DESIGN AT THE IHI TOKYO HEAD OFFICE

The basic design group of the IHI Head Office (Tokyo) is composed of approximately 100 persons primarily involved in creating the design of new vessels to be built at one of the IHI shipyards. Working in conjunction with the Marketing Survey Group, the Initial Development Group, and the Sales and Estimation groups, the Basic Design Group develops a conceptual ship design into a basic design package which consists of specifications, ships lines, general arrangement drawings, midship section drawings and naval architectural data and calculations.

The basic design office is organized into three groups according to vessel size and functional responsibilities as illustrated in Figure 1-2. The No. 1 Basic Design Group for small and medium size vessels and the No. 2 Basic Design Group for large vessels (super tankers) are referred to as “think tanks”. The educational level of these groups is high with 85% holding college or university engineering degrees.

In support of these two groups is the No. 3 Basic Design Group which is further broken down into four groups: 1) the Administration Group which performs the clerical functions of the department; 2) the Ship’s Form Group; 3) the Hull Structure Group both of which are composed of naval architects; and 4) an Electric Group composed of electrical engineers.

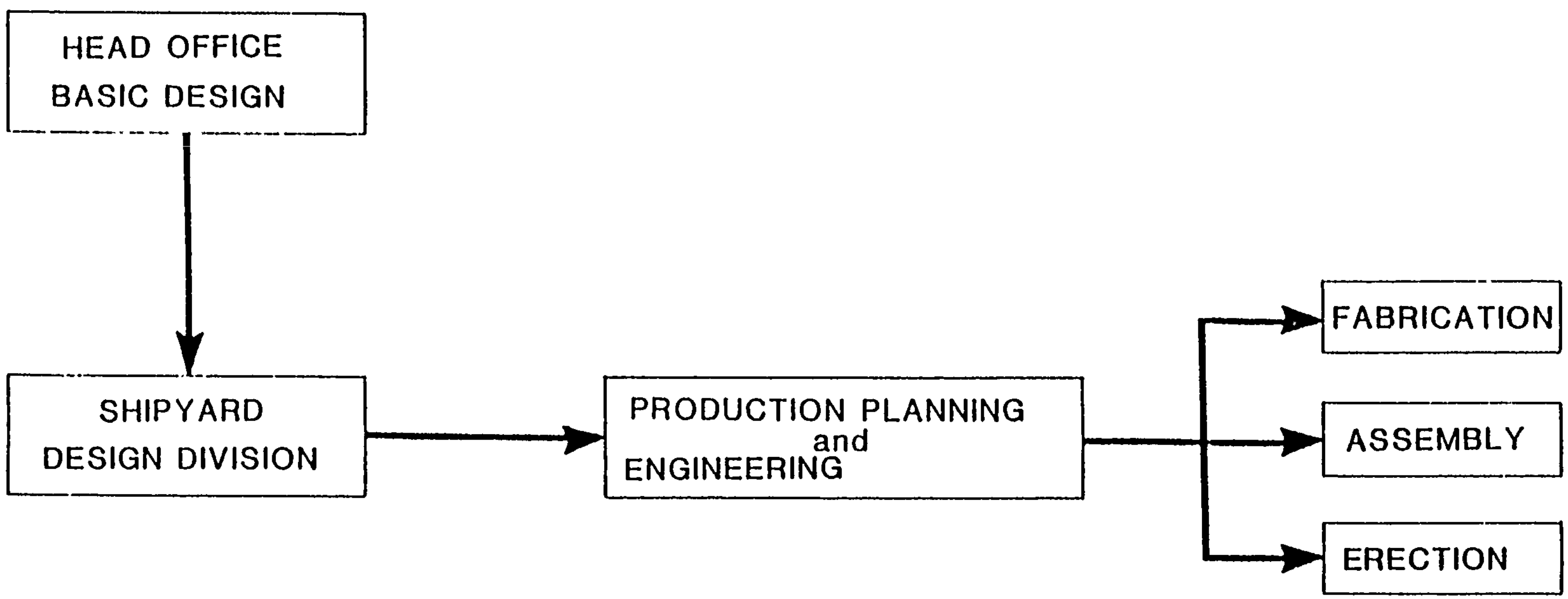


FIGURE 1-1

BASIC FLOW OF DESIGN FOR PRODUCTION

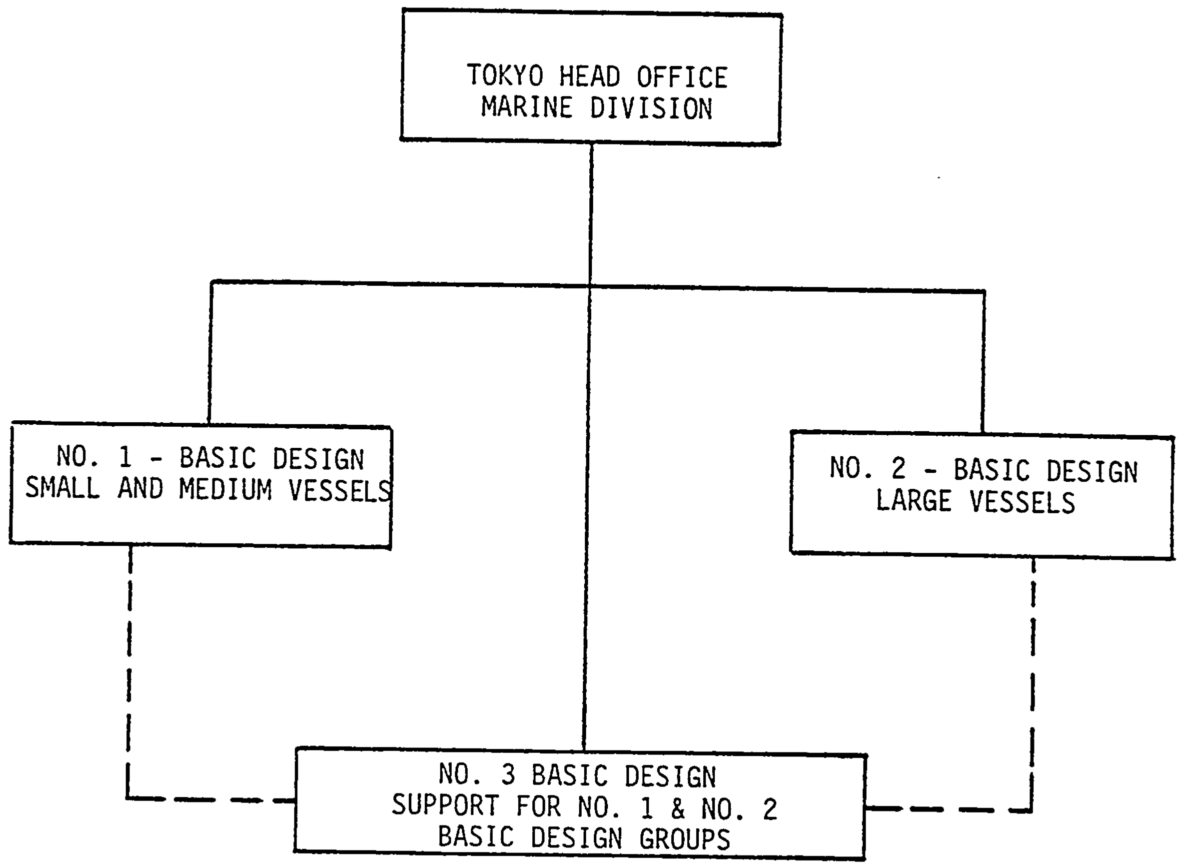


FIGURE 1-2

BASIC DESIGN OFFICE

The Basic Design package is the basis for the development of the Key Plans for the ship being designed. Computer output is utilized in preparation of the key plans as the drawings are rapidly produced at l/100th scale. These drawings are not finished at the head office but are transferred to a shipyard to be completed.

A preliminary blocking plan, or unit breakdown, is also prepared at the head office to be finalized at the shipyard selected to build the vessel.

SHIPYARD DESIGN & ENGINEERING ORGANIZATION

The Shipyard Design Group is directly responsible to the Shipyard General Superintendent and is divided according to the following major functions: basic design, key plan, yard plan, and computerization. The functions of these groups begin upon receipt of basic design data from the head office design division.

The shipyard's basic design group is responsible for maintaining specifications, customer requirements, and general arrangement drawings. This group also provides detail naval architectural data.

The key plan group prepares detail scantling data, schematic diagrams and functional plans, purchase order specifications, lists of materials for procurement, outfitting materials fabrication drawings, and material lists for fabrication drawings.

The yard plan group, or working drawing group, prepares detail fabrication drawings, detail outfitting drawings, material lists for outfitting, pipe piece manufacturing drawings, and material lists for pipe piece manufacturing drawings. Figure 1-3 illustrates the organization of the shipyard design department and Table T1-1 lists the specific functions of each group.

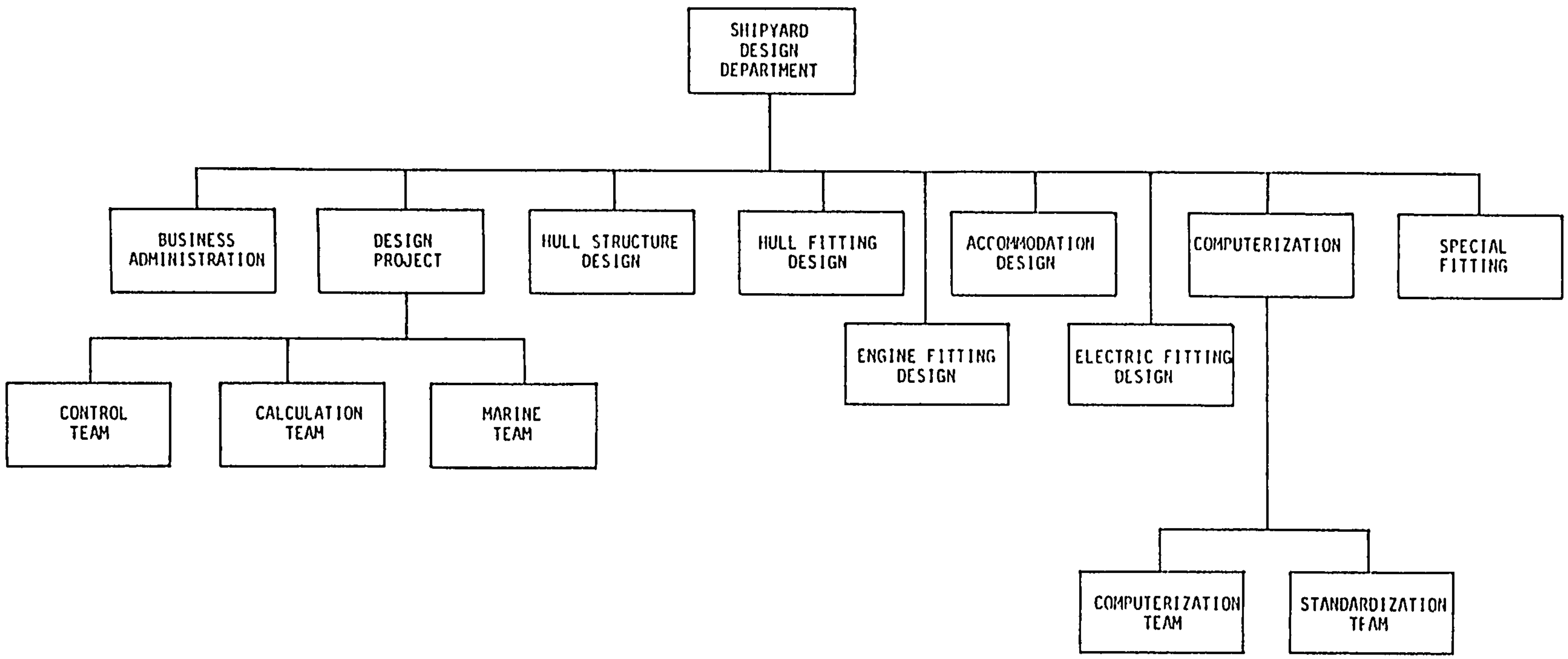


FIGURE 1-3

DESIGN DEPARTMENT ORGANIZATION

TABLE T1-1

MAJOR FUNCTIONS OF SHIPYARD DESIGN DEPARTMENT GROUPS

1. Business Administration Group

   l General service for each design section
   l Drawing schedule
   l *Working* schedule
   l Estimations

2. Project Design Group

   a. Control Team l Administration of each design group
   b. Calculation Team * Calculation of ship's properties
      l Tonnage Teas Teasurement
   c. Marine Team " Consultant work and drawing supply for overseas shipyards

3. Hull Structure *Design* Group

   * Key plans of hull structure
   l Yard plans of hull stcructure
   l Block *(unit) arrangement*
   * List of hull structural members including weight and fillet weld length

4. Hull Fitting Design Group

   l Key plans *of* hull fittings and piping
   l Purchase order specifications for fittings
   l Fitting arrangement plans
   l Production drawings of null piping and outfitting
   * MLF, MLS

5. Accommodation Design Group

   l Key plans of accommodations quarters
   l Joiner arrangement
   l List of upholsteries and fittings
   * Purchase order specifications
   l Production drawings of accomodations quarters
   l Key plans and yard plans of superstructure

6. Engine Fitting *Group*

   l Machinery arrangement
   * Piping diagram *of engine room*
   l Purchase order specification
   l Sea trials plans
   l Production drawings *of* engine room
   * Funnel fittings
   * Tanks and auxiliary foundations

7. Electric Fitting Design Group

   * Wiring diagram
   * Purchase order specifications
   l Electric fitting arrangement
   l Equipment for lighting and cable installation

8. Computerization Group

   l Systems and programs development
   l Maintenance of programs and manuals
   l Standardization of fittings

9. Special Fitting Design Group

   * Design of cargo gears and hatch covers
   l Design of rampways, stern and bow doors, special racks and carriers, etc.
   * Purchase order specifications
   l Heavy lifts, dredging, etc.

TYPICAL DESIGN SYSTEM AND FLOW

Through cooperation of all sections of the Shipyard Design Department, the basic drawings are finalized and submitted to the ship owner for approval. The drawings are then distributed to the various sections of the yard's design department to become Key Plans and eventually Yard Plans.

The basic design drawings consist of general arrangement, ship's lines, preliminary machinery arrangement, miship section, specifications, and calculations. These data are expanded to make up the Key Plans. The Key Plans describe the vessel in further detail in areas such as the fore body and after body. These drawings will then become the basis for the working drawings or Yard Plans.

The basic flow of drawings is illustrated in Figure 1-4. Table T1-2 shows the major items produced by the shipyard design organization.

Development of Key Plans

The key plans and hull calculations are prepared by the key plan teams of the Hull Structural Design Group, the Hull Fitting Design Group and the Accommodation Design Group. The structural design is analyzed using IHI computer programs "Z Plate" and Z Vibra" (see Appendices). The outputs from these programs are both printed and plotter-drawn.

Standardization and computerization significantly enhance the productivity of the design function. Many drawings are rapidly produced on a drum plotter, thus utilizing the computer data bank of ship's information. The Hull Structure Group prepares the loading information for the data base which in turn produces the shell landing data. This

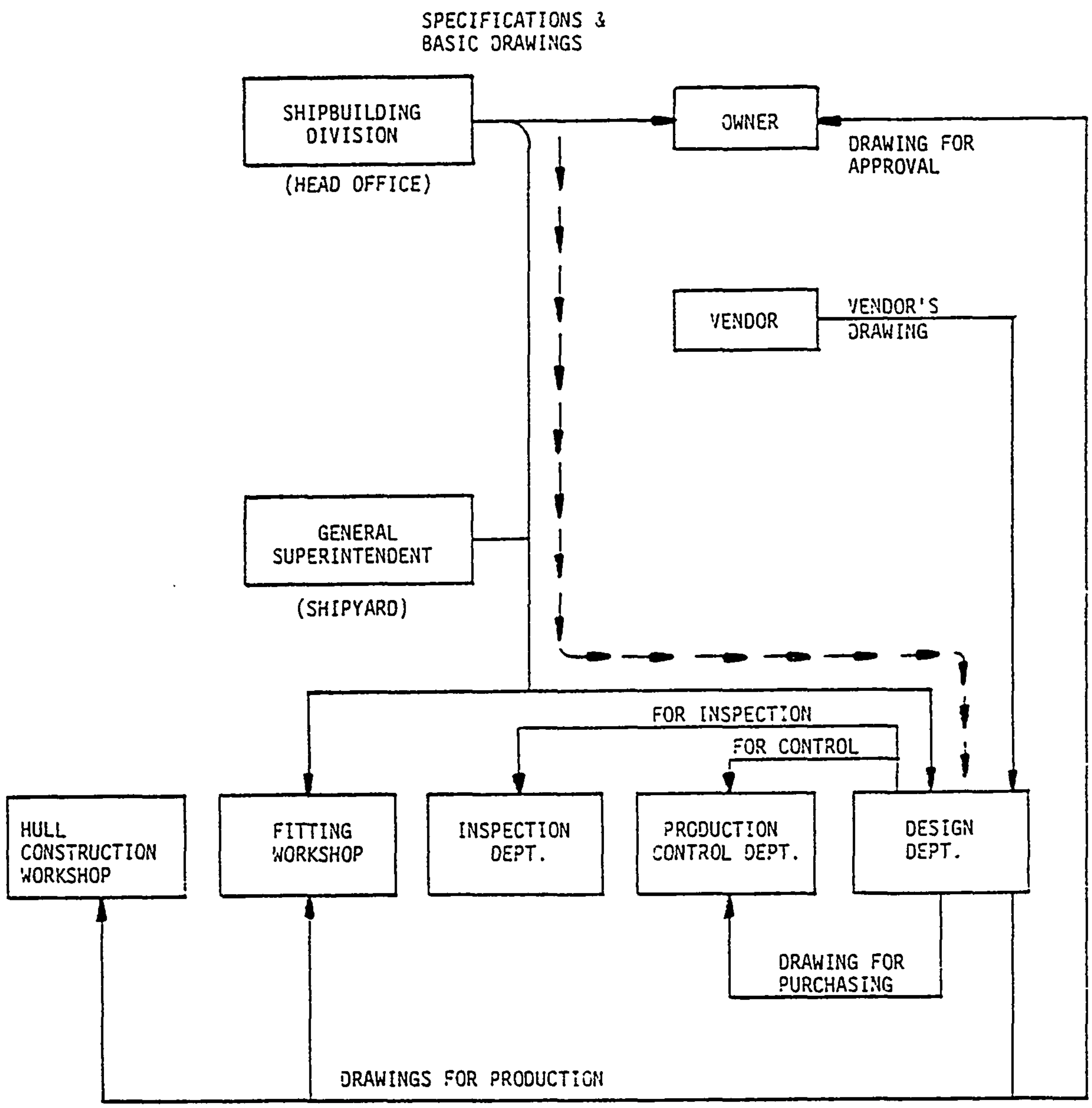


FIGURE 1-4

BASIC FLOW OF DRAWINGS

MAJOR ITEMS PRODUCED BY SHIPYARD DESIGN ORGANIZATION

*OUTFITTING KEY PLANS

- Machinery Arrangement
- Joiner Arrangement
- Piping Diagram
- Purchase Order Specifications (Main Machinery)
- MLS (Long Term Delivery Items)
- MLS (Material List by Systems)

HULL KEY PLANS

- Hull Scantling
  Unit Weight (Approx.) Preliminary Unit Arrangement
- Midship Section & Typical Transverse Bulkhead
- Stern & Rudder
- Main Eng. & Equip. Foundations
- Plan of Welding
- Stress & Vibration Research

*OUTFITTING YARD PLANS

- Compartment Arrangement
- Pallet List
- Composite Drawings
- Manufacturing Drawings (MLP, MLC) Manufacture of Pipe and other Components
- Module Assembly Drawing
- On-Unit Fitting Drawing
- MLF
- Purchase Order Specs (Short Term Del i very Items)
- On-Board Fitting Drawings

HULL YARD PLANS

- Unit Arrangement
- Unit Weights - Exact
- Unit Center of Gravity
- Welding Length
- Working Drawings & Structural Details
- Piece List
- Auxiliary Equipment Foundation Drawings

*Outfitting Design is divided into deck, accommodations, machinery and electric groups.

TABLE T1-2

input is normally entered via CRT but may be prepared manually and checked on a graphic display. The plotter is suitable for lines and shell expansion drawings and is also utilized for structural analysis by producing drawings which show structural diagrams and plotted stress locations.

The data are also used by the mold loft which is equipped with remote stations composed of a CRT and three large, automatic flat-bed drafting tables. Through these machines, design information reaches Production in the form of 1/10 scale, highly accurate, shape templates used in the fabrication of hull parts.

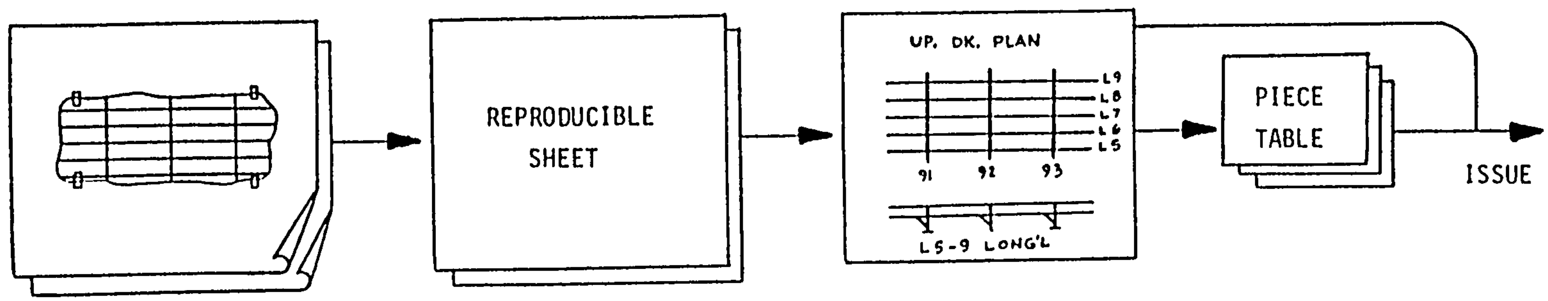
Development of Yard Plans

The next step in the shipyard's engineering process is the preparation of Yard Plans or working drawings. All hull structural detail information, block (or unit) arrangement, unit weights, weld lengths, center of gravity of units, piece lists and auxiliary foundation drawings are developed at this time.

The IHI drawing system is structured in such a way that a minimum of re-drawing is necessary. The drawings and material lists are prepared by various sophisticated photographic methods as well as computerized and manual drawing techniques.

The yard plan drawings are made according to the unit arrangement and consist of a title sheet and several sheets comprising the structure and details of an individual unit. Figure 1-5 depicts the process flow for preparation of the Yard Plans.

The issuance of the Yard Plans usually begins at K-3-l/2 (keel lay minus three and one-half months). Table T1-3 describes the



Parts of Key Plans are cut out, arranged and pasted up for reproduction. Key Plans are 1/100 scale.

Reproducible sheet is photographically enlarged to 1/50 scale.

Details, sections and other descriptions are added manually.

Piece tables are made for each unit including piece descriptions, piece weights and unit weight.

FIGURE 1-5

PROCESS FLOW OF YARD PLAN PREPARATION

TABLE T1-3

CONTENTS OF YARD PLANS

1. Principal Material List - the basic list of all materials to be used. By studying this list, the volume of fabrication work can be estimated.

2. Drawing List (MLA)- the kinds of drawings to be prepared by the yard's design department and the dates of completion.

3. Arrangement Drawings - indicate the arrangement of the ship as a whole, as well as the arrangement of the main equipment. These drawings describe the types of fabrication work to be done and serve as the basis for the fitting drawings. The block (or unit) arrangement *shows* all blocks of the vessel and provides the frame of reference for design and production of each vessel.

4. Body Plan (Hull Construction) - provides details of the hull structure and serves as a basis for the fitting drawings.

5. Diagrams - Indicate the functional systems of all outfitting equipment and serve as a basis for fitting drawings. Some diagrams are used directly in outfitting work as well as for systems performance checking.

6. Practices - contain the items of agreement *or rules* for actually carrying out the design work as well as fabrication work. They contain detailed instructions *not* found in the specifications.

7. Manufacturer's Drawings - are drawings of the auxiliary machinery to be fitted on the ship. The drawings are used by sub-contractors in the manufacture of items not made in the yard. They are used as reference material for the installation and operation of equipment.

8. Fitting Drawings - indicate the mounting positions of outfitting equipment and are the main drawings used by the Outfitting Department. Virtually all actual fitting work is done on the basis of these drawings. They are prepared by work stage and work zones.

9. Materials List (MLF) - contains all outfitting materials necessary for advancing the work based on the fitting drawings.

10. Piece Tables - are used when manufacturing pipes and are the basic drawings used at the pipe shop. The pipes in the fitting drawings are picked up one by one and a drawing is prepared for each. These drawings are grouped by MLF units.

actual contents of the numerous and varied drawings and the list of yard plans that are actually distributed to the worksites.

HULL CONSTRUCTION ENGINEERING

Shipyard design activities typically accomplish a great deal of the production planning associated with the development of the detailed working drawings. However, the principal activities of the design division of the yard are to identify and define the material which is to be procured versus that which is to be manufactured internally and the design for manufacture. From the top-level drawings and specifications, the details of the ship are progressively developed to the lowest level necessary for the fabrication of parts and pieces, sub-assembly of individual components (both hull parts and outfitting parts), assembly of hull units and final erection of these units on the ways. Figure 1-6 shows the development and progression of drawings.

Throughout the design development, detail planning and scheduling is performed by a consolidated group of design engineers, planners and production engineers. This planning is part of the design process in that an iterative cycle of design - planning - design occurs at each level of drawing development. On the basis of the top-level design the hull is subdivided into major hull units suitable for handling, outfitting and erecting. Subsequently, each unit is further divided into its detailed parts which are identified on material lists for either procurement or manufacture. Design engineers progressively detail each level of the ship breakdown in drawings of units, sub-assemblies of hull and outfitting components and detail parts and pieces.

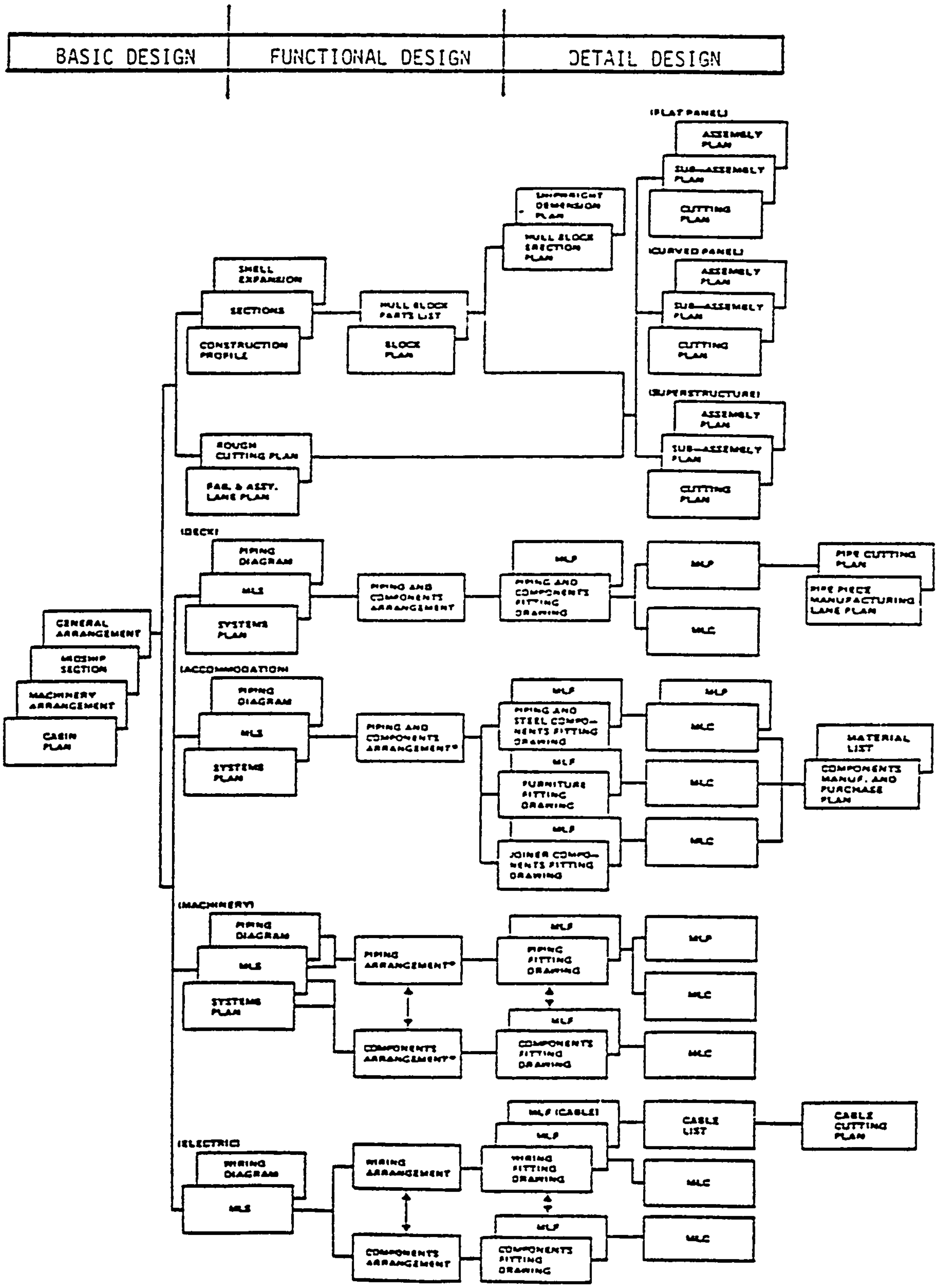


FIGURE 1-6

DESIGN DEVELOPMENT

As part of the planning/detail design development process, a series of planning documents are developed. Detailed assembly procedures are documented for each unit in Assembly Specification Plans and a series of Working Instruction Plans provide data relevant to: Marking, Cutting and Bending of plates during fabrication; Unit Parts Lists, Finish Dimension Plans for each unit; Sub-assembly Plans; Assembly Plans; Assembly Jig Size Lists; and Lifting Instruction for each unit. Working Instruction Plans are also prepared for specific elements of the erection process, such as: the Unit Arrangements Plan; Shipwright Dimensions Plan; Support Block Arrangements Plan; Welding Instructions; and a Scaffolding Arrangements Plan.

Simultaneously with the design development and production planning, Accuracy Control Engineers designate the critical dimensions of the procured and manufactured components and units to assure the highest accuracy of the product at each stage of production. This Accuracy Control activity greatly influences the design and the selection of the production processes to be utilized. Figure 1-7 depicts the concept of Accuracy Control in IHI.

Throughout this design process Production Planning and Engineering personnel attached to each of the Panel, Hull and Outfitting Workshops, provide appropriate production information and requirements to the designers. The working drawings and plans are carefully prepared to closely match facility and production organization capabilities.

OUTFITTING ENGINEERING

Design and Material Listing

The basic design planning for outfitting occurs during the evolution of the Basic Design into the detail working drawings. Subsequent

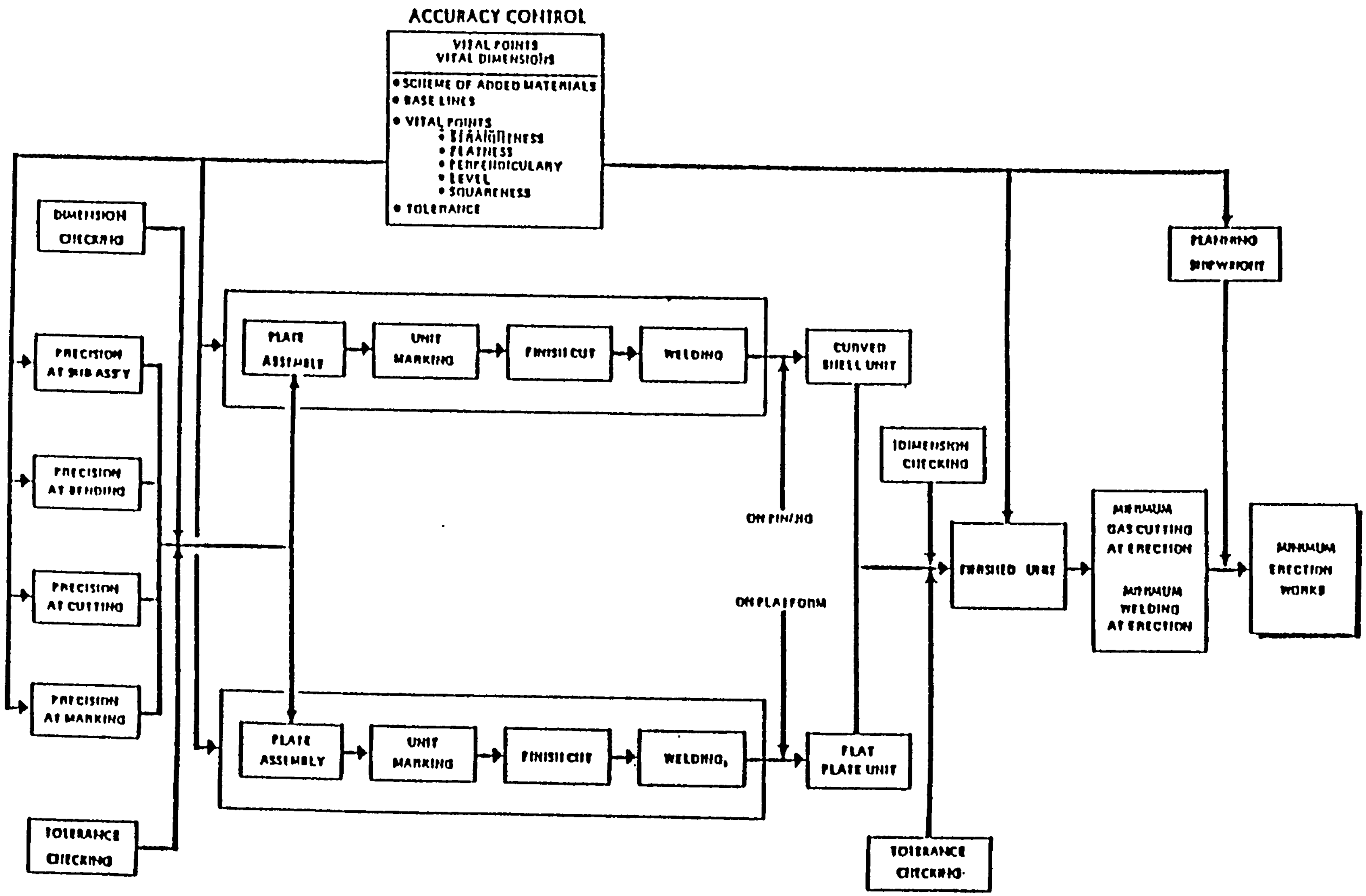


FIGURE 1-7

CONCEPT OF ACCURACY CONTROL IN IHI

to receipt of the Basic Design, the shipyard design department, in collaboration with the Fitting Workshop Production Planning and Engineering staff, develops system diagrams for each functional system of the ship. These diagrams do not reflect any sub-division of the ship into units. The diagrams do however, define all components required in each functional system. On the basis of these diagrams, a Material List by System (MLS) is compiled. These lists provide an itemization of the bulk and raw materials and system components required for a particular Material Ordering Zone. Figure 1-8 provides an example of an MLS.

IHI establishes a series of "Zones" for each ship: major zones, which are primarily used for sub-dividing the ship for the purpose of hull construction; Material Ordering Zones, which are used to categorize material for procurement; Outfitting Zones, which designate major areas of outfitting; and, Outfitting Work Zones, which are further sub-divisions of Outfitting Zones into discrete small packages of outfitting work. Figure 1-9 illustrates these different types of zones.

The system diagrams developed by the Engineering Department are part of the second stage of design development which is called "Functional Design". This stage takes the Basic design to the next logical level of development, i.e. Detail Design.

During the detail design stage the data from the functional design is converted into working drawings of unit assemblies, sub-assemblies, detail parts and pieces, etc. Also at the detail design stage an Outfitting Zone Plan is developed for the ship. An "Outfitting Zone" is simply a geographical area (3-dimensional) of the ship having no relation to a particular system. Instead, all systems within a given

MLS 番船別装置部品表

構成品コード UTL. CODE		品名 DISCRIPTION	取付符号 PIECE NO.	CODE	単位	No. 数量 (NET) / 数量 (GROSS)	WT 単重 (NET) / 重量 (NET)	引当図番	手配区分 SUB ZONE		備考
403002015	1	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 FR/042V	A32	1	10 10	1040 1040		34X171---0 34X171---0	11117	98 18391 0800
403002015	1	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 FR/043V	A32	1	10 10	1040 1040		34X171---0 34X171---0	11117	98 18391 0800
403002015	1	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 LO-025V	A32	1	10 10	1040 1040		34X186---0 34X186---0	11117	98 19177 0800
403002015	1	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 LO-026V	A32	1	10 10	1040 1040		34X186---0 34X186---0	11117	98 19177 0800
403002015	1	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 LO-027V	A32	1	10 10	1040 1040		34X186---0 34X186---0	11117	98 19177 0800
403002015	1	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 LO-028V	A32	1	10 10	1040 1040		34X186---0 34X186---0	11117	98 19177 0800
403002015	1	** SUB-TOTAL	**		100						
		** SUB-TOTAL	**		100		10400		34		
403003008	1	FC S.D.C.GLOBE VALVE FC/BC FN 5050GB	31,30,00 BS-222V	A32	1	10 10	148 148		34XM1AP--0 34XM1AP--0	11117	98 18392 2 0800
403003008	1	** SUB-TOTAL	**		10						
		** SUB-TOTAL	**		10		148		34		
403003009	1	FC S.D.C.GLOBE VALVE FC/BC FN 5065GB 922348 362902	32,60,00 FO-019V	A32	1	10 10	213 213		34X118---0 34X118---0	11115	0800
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		** SUB-TOTAL	**		10		213		34		
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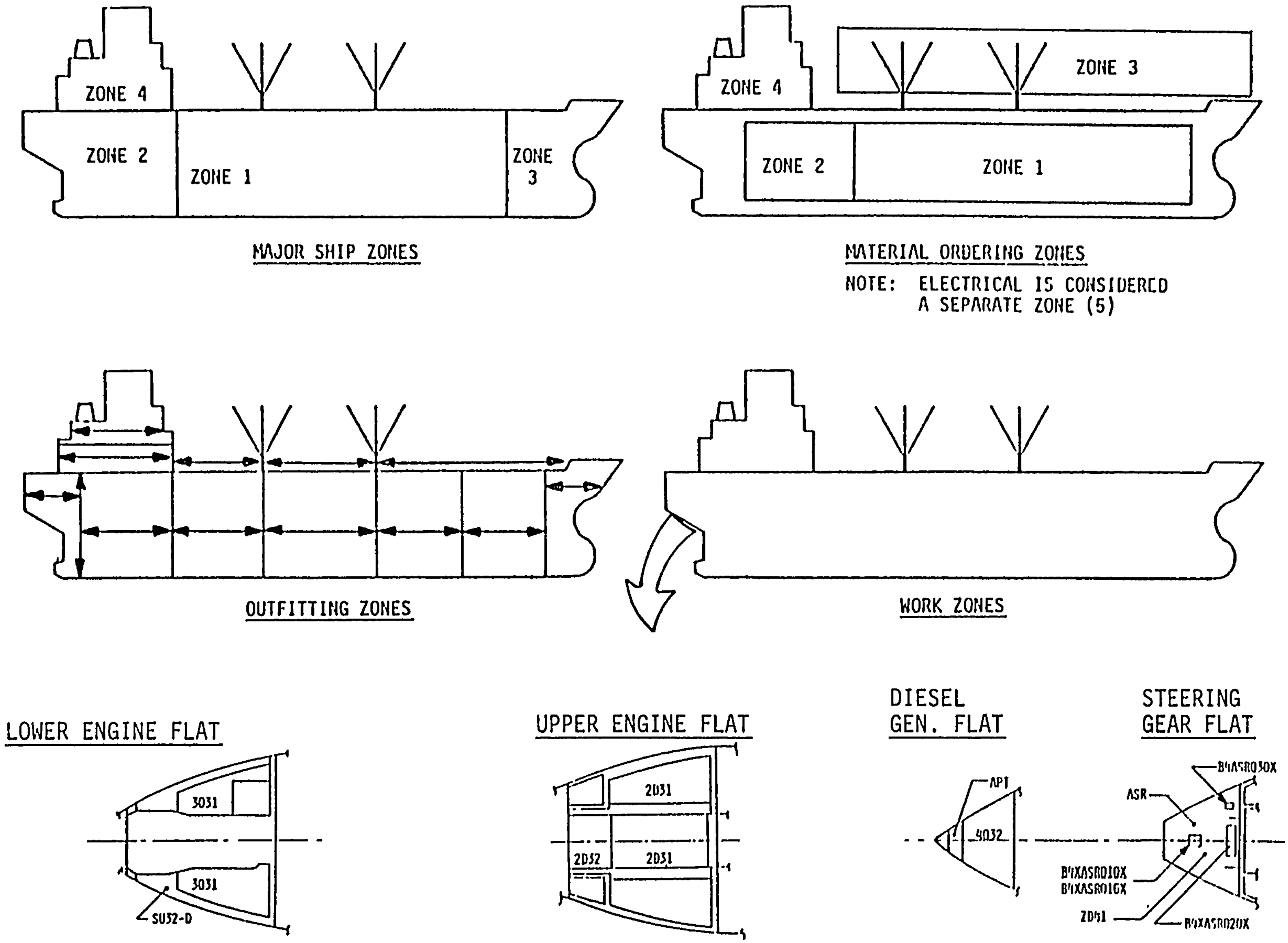
FIGURE 1-8

MATERIAL LIST BY SYSTEM



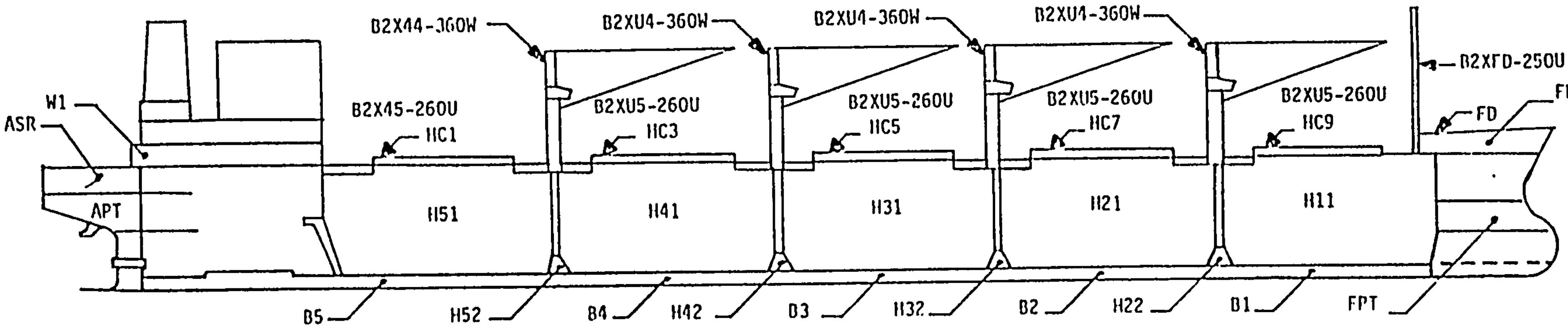
ZONE 4
ZONE 2
ZONE 1
ZONE 3
MAJOR SHIP ZONES
ZONE 4
ZONE 3
ZONE 2
ZONE 1
MATERIAL ORDERING ZONES
NOTE: ELECTRICAL IS CONSIDERED A SEPARATE ZONE (5)
OUTFITTING ZONES
WORK ZONES
LOWER ENGINE FLAT
3031
3031
SU32-D
UPPER ENGINE FLAT
2031
2032
2031
DIESEL GEN. FLAT
APT
4032
STEERING GEAR FLAT
ASR

area are encompassed by the zone boundaries. Figure 1-10 illustrates the Outfitting Zones identified for one type of ship.

With the identification and designation of Outfitting Zones, detailed material lists are formulated together with piece drawings for the manufacture of pipe pieces, piping arrangements, and outfitting pieces and sub-assemblies. Specific material lists are prepared for the manufacture of pipe (Material List for Pipe - MLP) and for other outfitting components (Material List for Components - MLC). These material lists and the associated piece drawings are eventually scheduled for production through the yard pipe or fabrication shops. Figures 1-11 and 1-12 present examples of these material lists.

In addition to the above, the detail design effort also produces composite drawings showing the layout of all outfitting material in specific "Work Zones" (a further breakdown of the outfitting zones into small packages of outfitting work). These composite drawings show the interrelationship of the many different systems integral to the individual work zones together with details of mounting and joining. Figure 1-13 provides an example of a composite drawing. (The composite drawing system will be further explained in subsequent paragraphs.)

Upon completion of the composite drawings, the final stage of design, Work Instruction Design, is initiated. This design stage produces drawings of outfitting components which are to be " installed at different production stages, e.g. sub-assembly, assembly erection, and after launch. Figure 1-14 illustrates this development from top-level design data to individual Work Instruction Drawings. Accompanying these drawings is another material list, the Material List for Fitting (MLF) which corresponds to the work to be accomplished at the production



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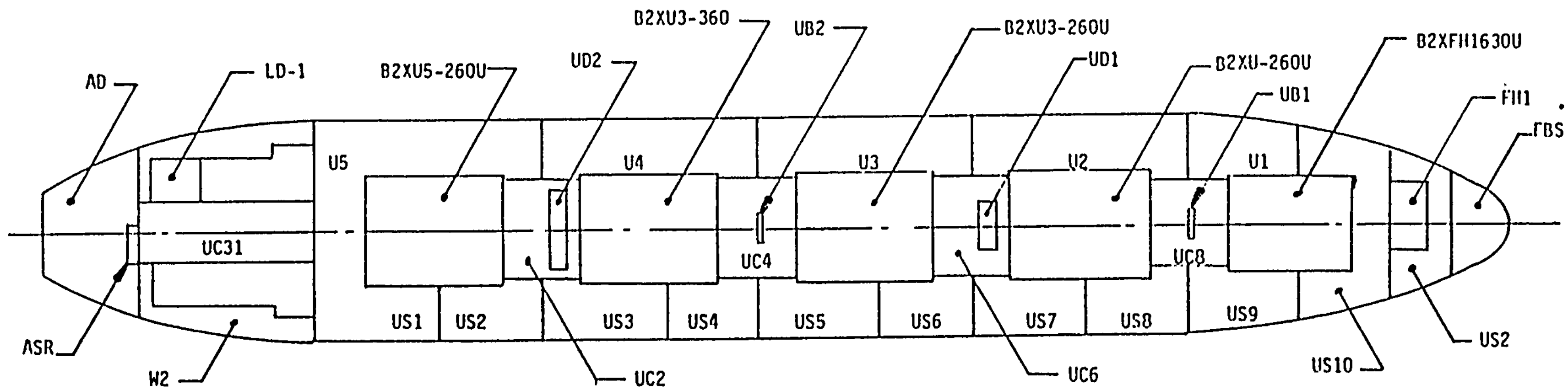


UPPER DECK

FIGURE 1-10

OUTFITTING ZONES

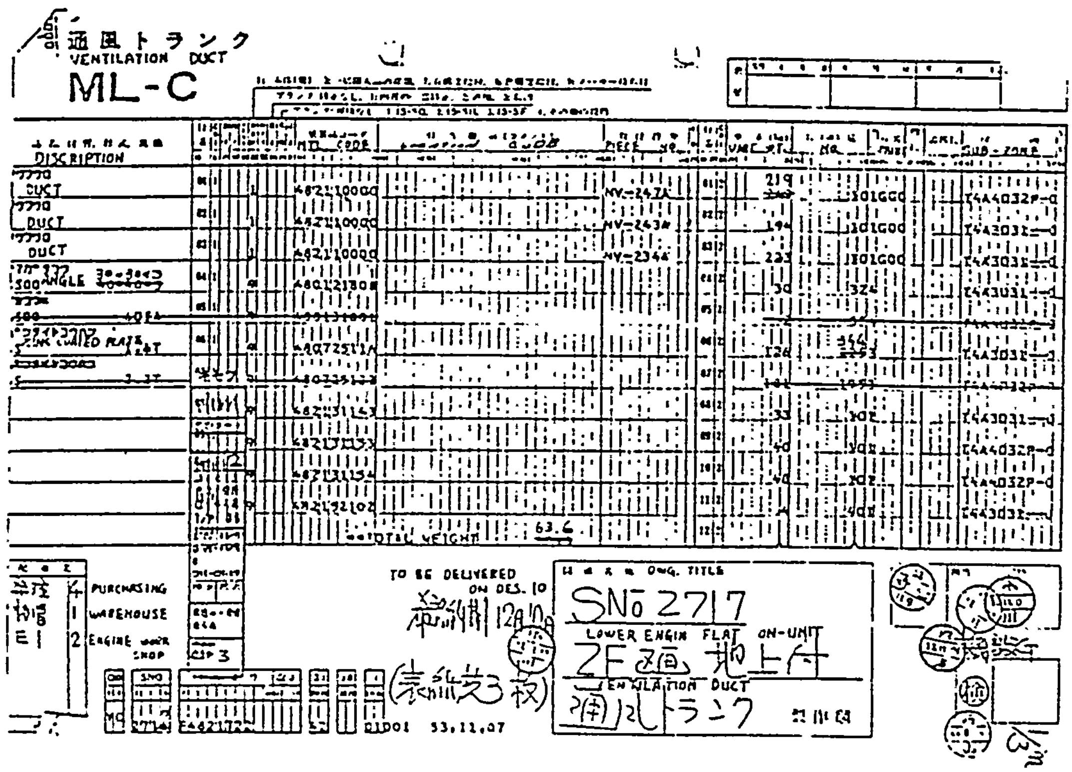
MATERIAL LIST FOR PIPE

MLP

DESCRIPTION	S NO	OUTFITTING CODE	C NO	MATERIAL CODE						WEIGHT
15A			94	161001	1			13	0	93.7
25A			94	161003	1			31	0	414.3
40A			94	161005	1			26	0	556.3
50A			94	161006	1			14	0	408.9
65A			94	161007	1			9	0	369,8
15B			94	162001	1			1	0	7.2
25B			94	162003	1			9	0	127.2
40B			94	152005	1			14	0	315.7
65B			94	162007	1			5	0	260.8
25C			94	162103	1			1	0	18.0
40C			94	162105	1			6	0	180.5
50C			94	162106	1			4	0	164.1
65C			94	152107	1			3	0	193.0
25CC			94	162118	1			1	0	18.0
40BB			94	162156	1			2	0	45.1
50BB			94	162157	1			2	0	59.3
65BB			94	162158	1			1	0	50.2
25CC NK			94	172022	1			2	0	35.0
40CC NK			94	172024	1			3	0	90.3
40CC AB			94	178024	1			1	0	30.1
40SC LR			94	184077	1			1	0	30.1
15B AB			94	188004	1			1	0	7.2
25B NK			94	188006	1			2	0	28.3
			94							
			94							
			94							
		TOTAL	94							3,499.5

FIGURE 1-11

MATERIAL LIST FOR PIPE



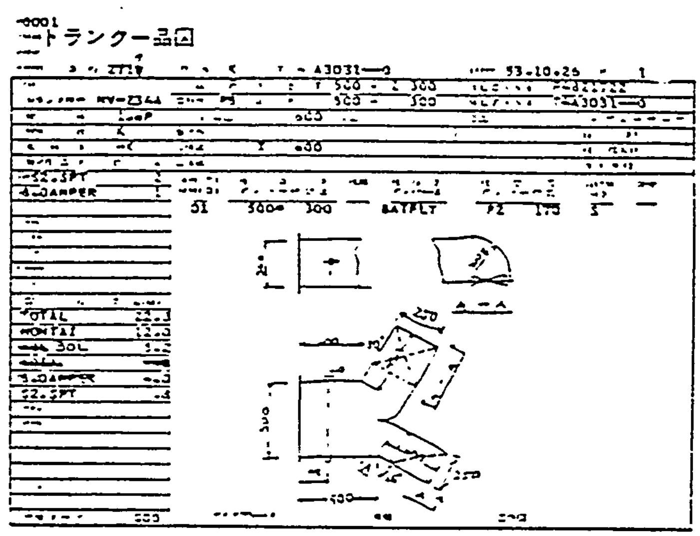


FIGURE 1-12

MATERIAL LIST FOR COMPONENTS

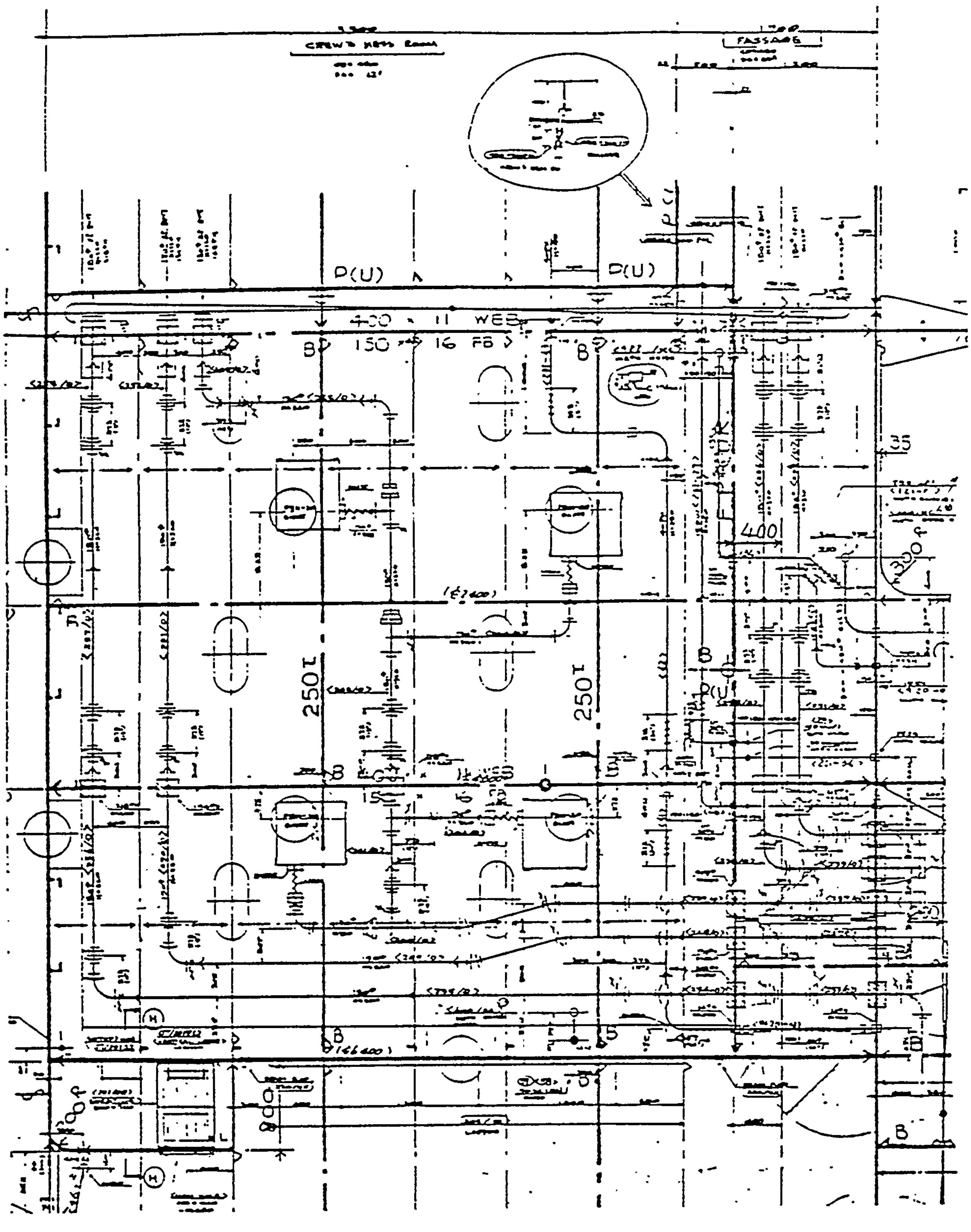


FIGURE 1-13

COMPOSITE DRAWING

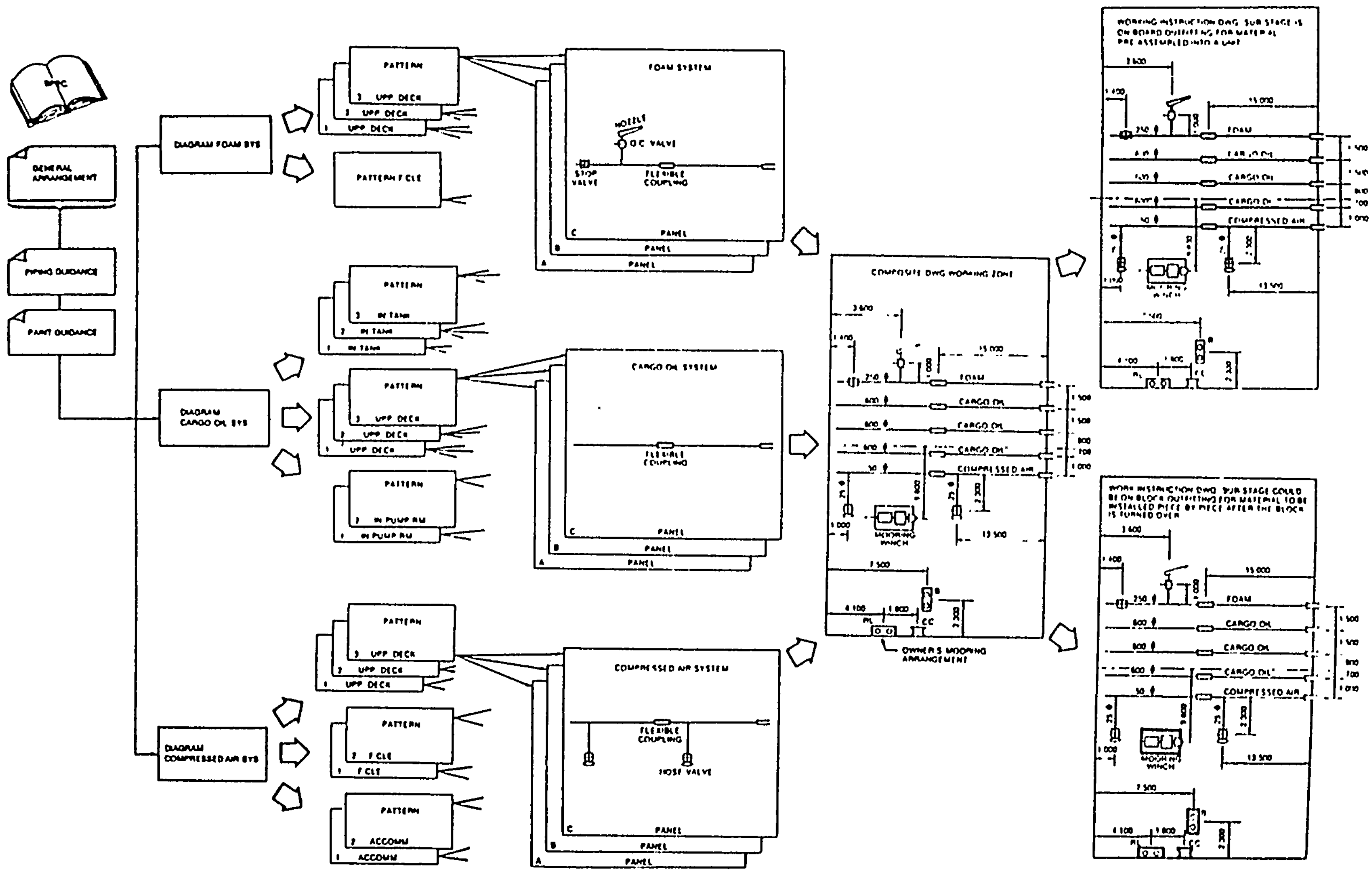


FIGURE 1-14

OUTFITTING DESIGN DEVELOPMENT

stage shown on the Work Instruction Drawing. Figures 1-15 and 1-16 provide examples of a Work Instruction Drawing and a Material List for Fitting, respectively.

The Work Instruction Drawing, the associated MLF, the procured components and the manufactured components (i.e. by the yard) comprise a specific work package or “pallet” as it is identified by IHI. The “pallets” of information and material correspond to the “work zones” established for a given outfitting zone.

Composite Drawing System

In IHI composite drawings are the primary source of information for the pre-outfitting of entire zones of a ship. Another name for the composite drawing system is the compartment outfitting method. All outfitting systems are shown in an outfitting arrangement drawing based on a compartment or zone of the vessel. This is in contrast to the system by system approach, which usually shows one or more entire piping system for a major portion of the hull, or event for the entire vessel .

IHI has realized many benefits from the use of composite drawings for outfitting, especially in the important area of piping. Through a coordinator between outfitting design sections, all interferences are dealt with on a day to day basis. The composite drawings are pre-pared to a drawing supply schedule which is relatively standard for a basic vessel type. As nearly as possible, all outfitting sections simultaneously work on drawings for the same area of the ship.

A Design Procedure and Drawing Supply Schedule, considered a management standard, provides enough lead time before actual start of fabrication for the necessary design and engineering work that must

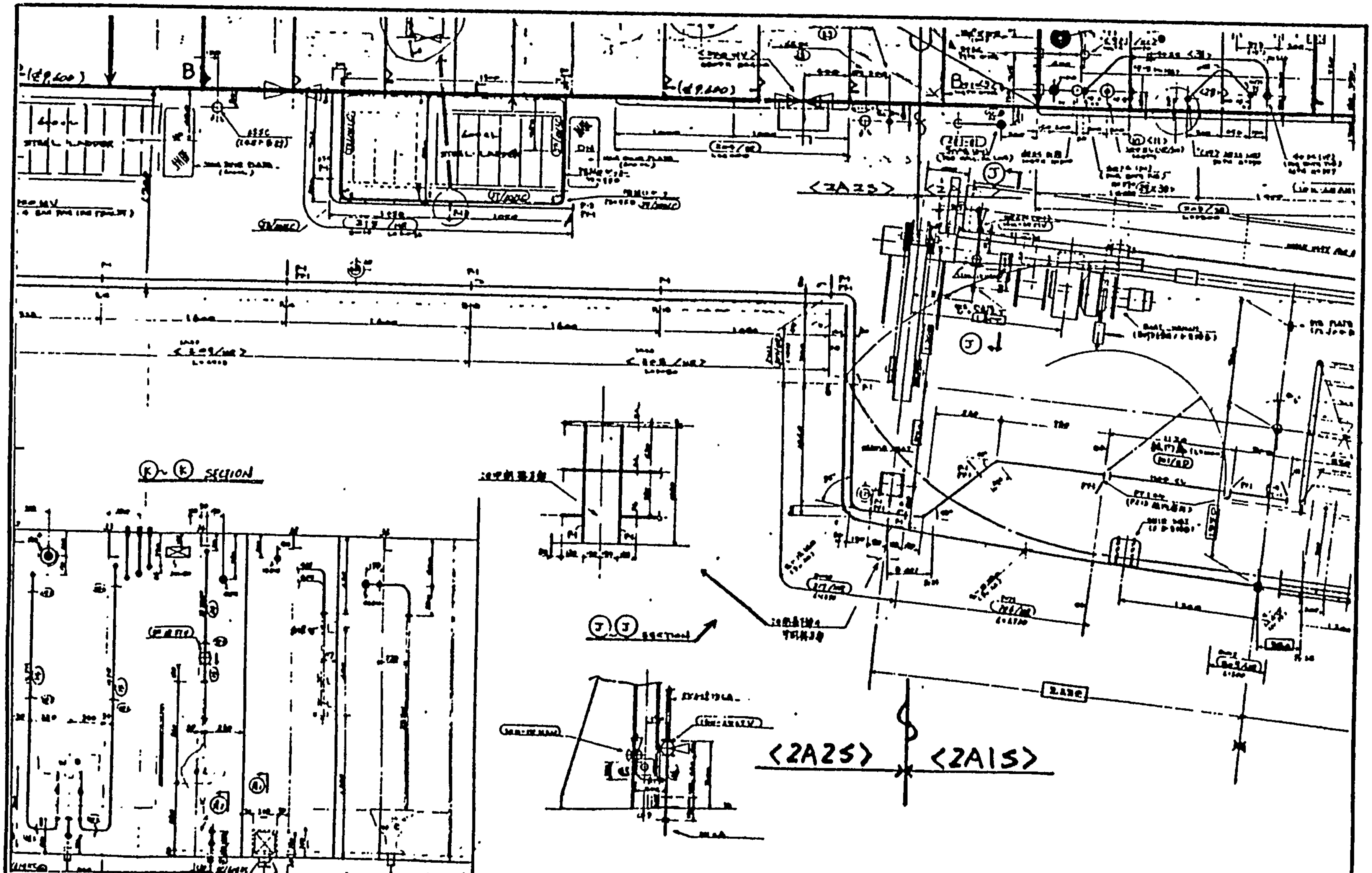


FIGURE 1-15

WORK INSTRUCTION DRAWING

A : Information for unit assembly.
F : Fabrication sign.
L : Temporary location sign for next stage.
U : unit of quantity
W : Indication of weight.

M L F

Date: 79. 05. 11

DESCRIPTION	A	Piece No	F	L	Specifications	Qty	U	W	Weight	Paint	Ref.Dwg No / MLF No for TLM	Mtl code	A	Remarks
BUTTERFLY VALVE(MANUAL)		SW-425V			FC25 SCS13 5K ♦ 200	1U	1	1	240	D42	N4044000	1404490000		♦
BUTTERFLY VALVE(MANUAL)		SW-426V			FC25 SCS13 5K ♦ 200	10	1	1	240	D42	N4044000	1404490000		♦
BUTTERFLY VALVE(MANUAL)		SW-472V			FC25 SCS13 5K ♦ 125	10	1	1	140	D42	N4044000A	1404490000		♦
BLIND FLANGE SS41 GALV.F8 5K 80SSO						1U	1	1	29	R44		4406010130	A	♦
WATER FILTER		SW-403S			5K-200C (200X250) FIREGS	1U	1	1	1410	D42	N4082400C	1408250900		♦
WATER FILTER		SW-404S			5K-200C (200X250) FIREGS	1U	1	1	1410	D42	N4082400C	1408250900		♦
FIRE & G S PUMP		MA-057AA			VEC 180/300M3/H ♦ 80/35M	10	1		10000		N4451160A	1445116000		♦
FIRE & G S PUMP		MA-057AB			VEC 180/300M3/H ♦ 80/35M	10	1		10000		N4451160A	1445116000		♦
MOTOR (FIRE & G S P)		P/FGR-M			75KW 1800RPM TE V 8	20	1		13200		N4451170	1445117000		♦
PIPE BAND SUPPORT					N=24	10	1	1	1872		F4634803	2463400000		♦
ORIFICE		SW-401W			10K ♦ 125	1U	1	1	07	D42	N4699300E	1469930000		♦
ORIFICE		SW-402W			10K ♦ 125 (D=39)	1U	1	1	01	NOP	N4699300D	1469930000		♦
VERTICAL LADDER		NG-100V			VFS-5 L/800	1U	1	1	110	D33	F4830212	2483620000		♦
VERTICAL LADDER		NG-101V			VFS-5 L/950	1U	1	1	131	D33	F4830212	2483620000		♦
FLOOR & GRATING		NG-070C				1U	1	1	905		F4831010	2483100000		♦

S. No	MLF - No	Req. date	next stage	Work Dwg. No.	Shop	BClength	Total wt.	Control wt	Erect wt	Page
2688	64Y057---0	79 06 01	74DPS315-0	2U01 -3	7 42 PNO.226		785 / 5171	785 / 5171	785 / 5171	5

(2232)

FIGURE 1-16

MATERIAL LIST FOR FITTING

precede the actual fabrication, assembly, erection and outfitting activities.

Concurrent with the preparation of the composite drawings, the material lists (MLF and MLP) are prepared. The MLF facilitates material gathering in advance of fitting. It corresponds to the fitting drawing which shows all material in a compartment or work zone. All oufitting pieces are numbered designating the compartment, system, and whether the parts are to be fitted on-unit or on-board. On-unit or on-board fitting designation may be made with a separate drawing (see Figure 1-17).

For all information necessary to fabricate pipes, separate pipe piece drawings are made. Piece drawings are actually breakdowns of a composite drawing showing each piece and fitting. A material list (MLP) is included on the piece drawing to show size, type, quantity, and material specification. This type of drawing is usually a three-dimensional view. Figure 1-18 provides an example of the kind of pipe piece drawing used by IHI.

The drawing package that is ultimately given to Production consists of the composite or compartment drawing, the fitting drawing, work instruction drawings and the MLF. In the production process, the fore-men use the composite for reference, whereas, the workmen rely on the fitting drawings, the work instruction drawings, and the MLF.

ADDITIONAL DESIGN AND ENGINEERING PLANNING

The Hull Construction and Outfit Planning discussed in the fore-going pages combine the aspects of design and production into a thoroughly defined set of working drawings and plans necessary for the

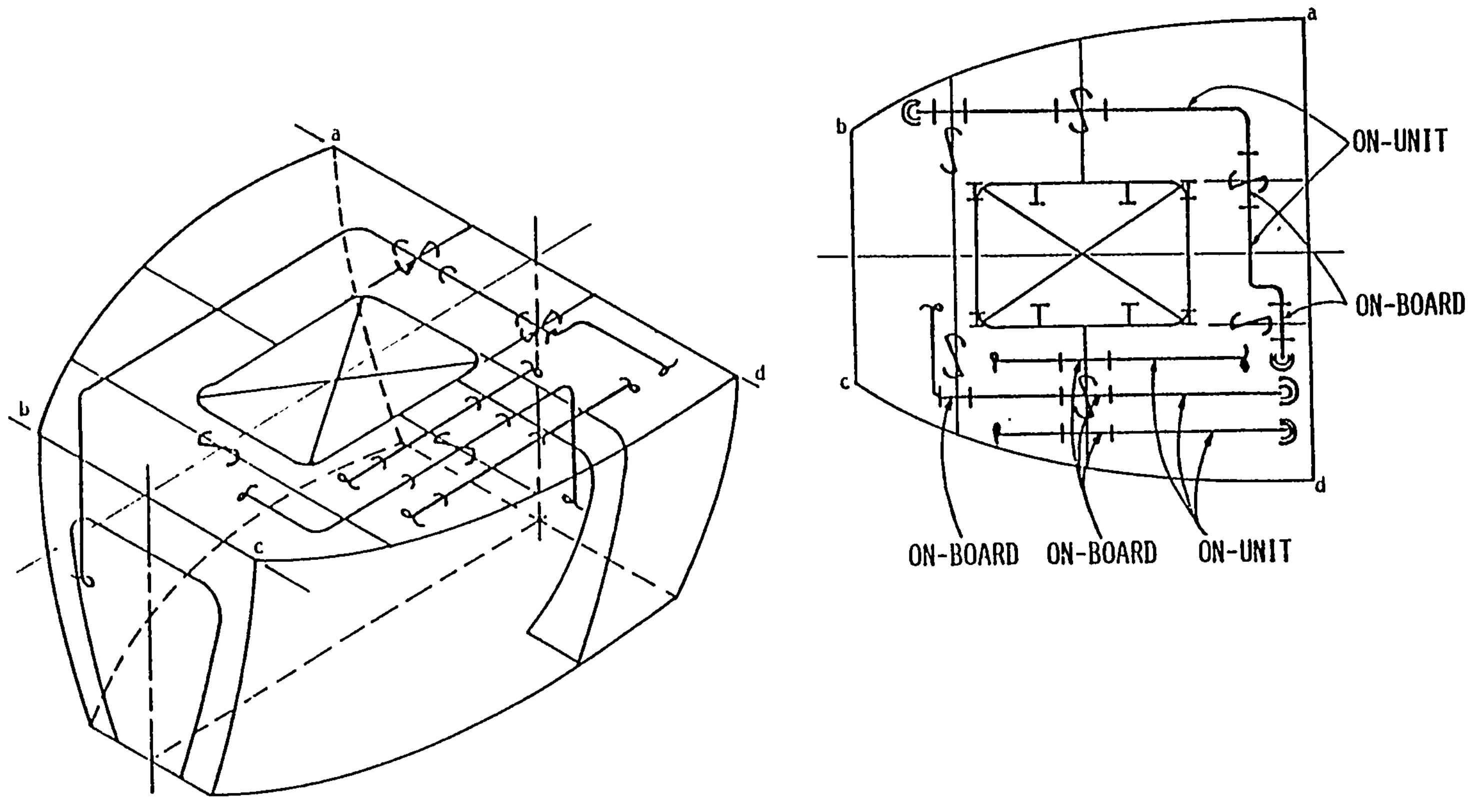
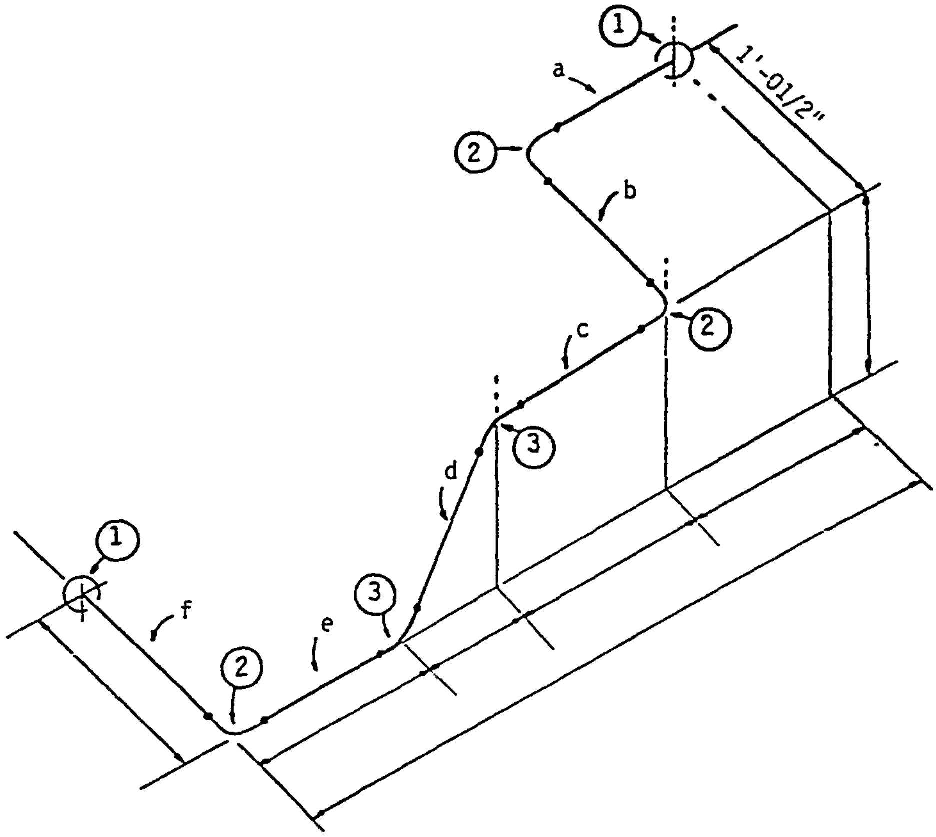


FIGURE 1-17

EXAMPLE OF DRAWING FOR DESIGNATION OF ON-UNIT OR ON-BOARD FITTING



MATERIAL LIST

QTY.	DESCRIPTION	MAT'L	PC. MK. RESULTS
2	3" 150# Flg	FS	1 FF
2	3" 45^{0} Ell Sch 40	BLK	3 BW
3	3" 90^{0} Ell Sch 40	BLK	2 LR BW
1	3" Sch 40 Pipe 2'1-1/8"	BLK	a
1	3" Sch 40 Pipe 0'3-1/2"	BLK	b
1	3" Sch 40 Pipe 3'9-1/2"	BLK	c
1	3" Sch 40 Pipe 3'0-1/16"	BLK	d
1	3" Sch 40 Pipe 0'5-9/16"	BLK	e
1	3" Sch 40 Pipe 0'2-3/8"	BLK	f

FIGURE 1-18

EXAMPLE OF PIPE PIECE DRAWING

(WITHOUT DIMENSIONS)

manufacture of the hull assembly units, the outfitting of those units and the erection and outfitting of the entire ship. This discussion has purposely omitted some types of planning (that occur simultaneously) in order to simplify the design process. However, it is important to cover these other planning aspects to complete the overview of this involved process.

Other plans are prepared by workshop engineering personnel to detail the methods for facilitating work during the erection stage and during on-board outfitting. This planning is called "Field Planning" and consists of the following types of plans:

Plan for temporary holes (in the hull during erection)

Plan for ventilation & cooling of the hull on the ways

Plan for supply of electrical power and gas lines

Plan for stools arrangement on the ways

Plan for equipment access on-board and on working staging

Plan for standard shipwrighting techniques

Plan for maintaining shaft alignment considering the initial hogging of the aft and forward ship sections

Plan for tank arrangement and testing

Plan for final dimension check items

Plan for disposal of temporary pieces for construction

DESIGN CHANGE CONTROL

System design changes occur because of regulatory body requirements, owner requirements, builder changes due to design changes or errors, builder changes due to production errors or methods changes, or vendor changes because of errors in drawing, changes in material or equipment, etc.

In IHI, the system for design change is initiated in the design department, regardless of the source of the change. In order to minimize rework and rescheduling, preliminary information regarding the change is accomplished quickly. To facilitate smooth incorporation of the design change into the total system, changes that have a big influence on schedule are dealt with at meetings held for the specific purpose of discussing design changes. On big items of change having effect on future vessels, information will be fed back into the design process.

The preliminary information system is immediately effected so that the change can be ordered to production before any rework is necessary. The formal information system is then effected to update all records and make all necessary notifications (refer to Figure 1-19). Thus, quick action to minimize cost and formal action to keep all records accurate are the two main objectives of the design change control system at IHI.

In the IHI Computer System (IHICS) for hull design, all design changes are quickly fed back into the system to minimize the negative effects of the change. The program is designed so that production corrections caused by design changes are minimized. Actual generation of physical data of parts can be postponed up to the execution of parts generation.

ENGINEERING ACTIVITIES--LAUNCHING TO DELIVERY

As is typical of practically all shipyards, the Shipyard Design Department is involved as an aid to Production during the time from launching through delivery of the vessel. Some of the main activities are:

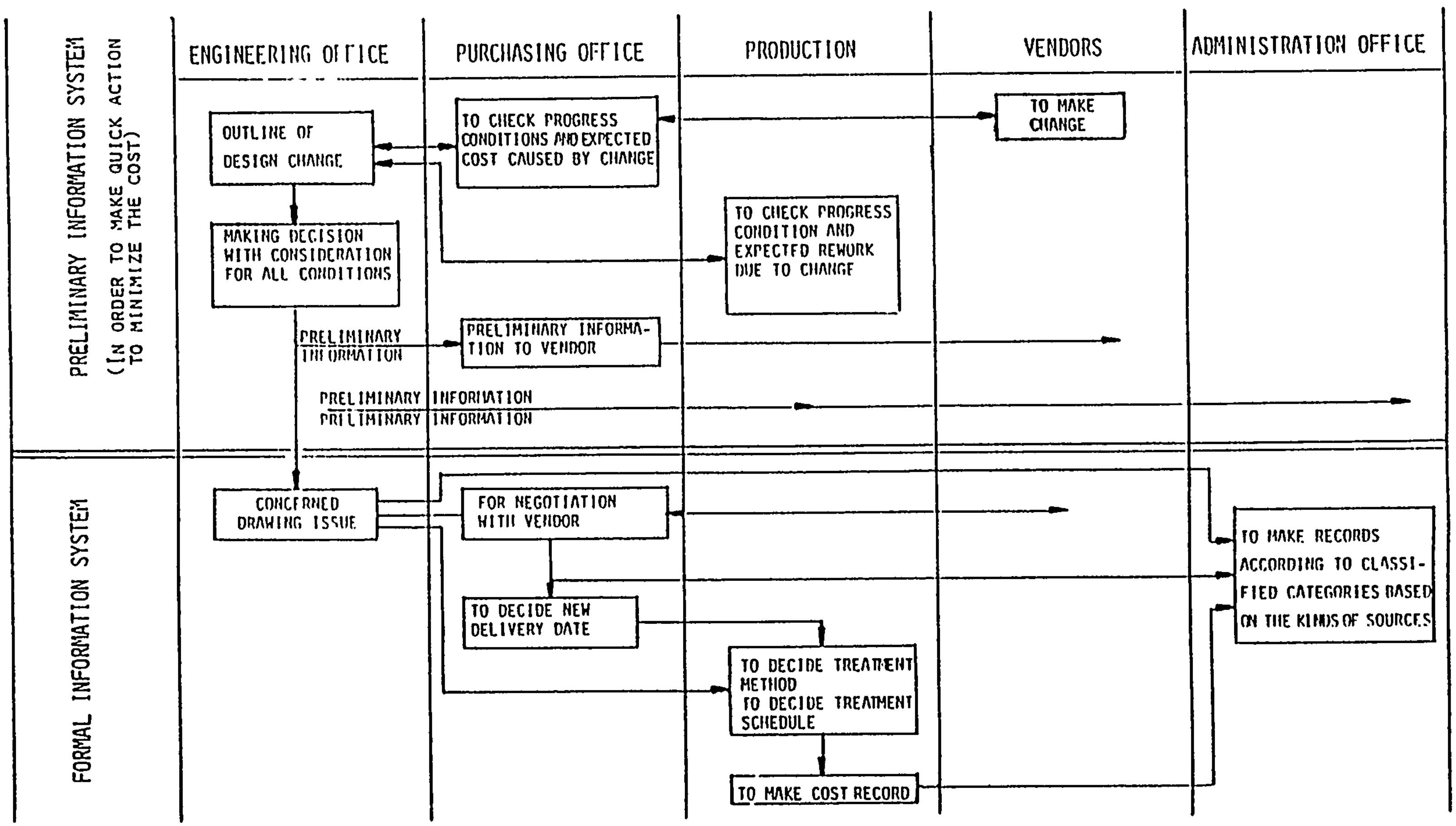


FIGURE 1-19

INFORMATION FLOW FOR DESIGN CHANGE

Launching

Incline Tests

Deadweight Measurement (Ship's Light Weight)

Plan of Equipment Testing and Sea Trials

Performance Confirmation

Ship's Operation Manuals

Finish Drawings to Reflect All Modification (Ship's Copy)

Provide Gross Tonnage Data According to Worldwide Requirements

COMPUTER AIDED DESIGN

Since IHI entered the field of computer aided ship design and manufacture, several main systems have been developed and extensively utilized at the IHI yards. These systems have applications throughout the design and production processes beginning with the Basic Design at the Head Office in Tokyo through the development of the Key Plans and the Yard Plans at the shipyard. These main systems are the result of breaking down the engineering work to be done into simple processes. This process definition facilitated the building up of program modules which perform the necessary data processing according to the type of work to be done and the required output. In this manner, the IHI computerization group has developed an integrated system of design oriented programs that share a common data base but perform independently to provide the data necessary for all phases of ship design and automated fabrication.

Computerization is relied upon in the Basic Design stage to perform structural analysis, propulsion performance analysis and maneuverability analysis. As the design progresses toward development of the Key Plans, all necessary ship's calculations for naval architectural data are also performed. As the Key Plans are finalized and the Yard Plans are begun, the Hull Design system is fully utilized from the fairing of ship's lines to hull piece design. Systems for outfitting design are also employed.

Production Engineering and Material management also rely on computerized systems. Purchasing and issuing material are functions of the Steel Plate Control System. There is also a Material Control System for new ship construction. The design oriented functions for Production Engineering are for Hull Piece Drawing, Nesting of Hull Plates, Hull Piece/Parts Control System and a Pipe Processing plan.

Scheduling and manufacturing utilize computerization for Hull Construction Scheduling, Outfitting Scheduling, Manhour Calculation, N/C (Numerical Control) High Speed Marking System, N/C Gas Cutting System, and N/C Frame Bending and Pipe Bending.

MAIN IHI SYSTEMS FOR COMPUTER AIDED DESIGN

IHICS, or Integrated Hull Information Control System, is a series of program packages which assists engineers in the fields of design and production engineering for hull construction, and also provides information necessary for production.

IHICS resulted from the necessity to standardize as much design data as possible and to correlate these data with the established production processes of the IHI shipyards. IHICS provides the following:

Generation of engineering and production data from a small volume of input data prepared by engineers.

Assistance to engineers in design and production engineering activities.

Creation of a data base which supplies the manufacturing division with production engineering data, numerical control data and piece lists for each stage of production.

IHICS is composed of the following three sub-systems: Basic Data Creation, Section Design and Production Engineering. Figure 1-20 describes these sub-systems in terms of their respective component programs in relation to the data base. Each of the program's functions are outlined in Table T1-4 which also outlines the program outputs.

COMPUTER AIDED DESIGN SYSTEM FOR PIPING

At IHI, computer aided design is utilized in the outfitting of vessels. Piping systems are automatically designed by the CADS system which is capable of designing new piping modules and modification of these modules when necessary. In addition to the automatically designed modules, the CADS system allows for input of manually drafted sketches of piping systems which will be processed and finalized as a usable design.

The basic flow of information into and from the CADS piping design system is outlined in Figure 1-21.

Figure 1-22 describes the process flow of piping design from basic design and functional design through drawing preparation for engineering and production.

Figure 1-23 illustrates the relationship of the CADS system in the preparation of detail piping design. As the transition from functional design to detail design is made, utilization of the CADS system begins. Both manually and automatically prepared data are processed by CADS.

Outputs of the CADS system utilize hull structure drawings to identify obstacles and interferences for piping. Main hull structures such as frames, longitudinal and decks are registered and drawn by the system. Three part drawings of piping plans show plan, side and

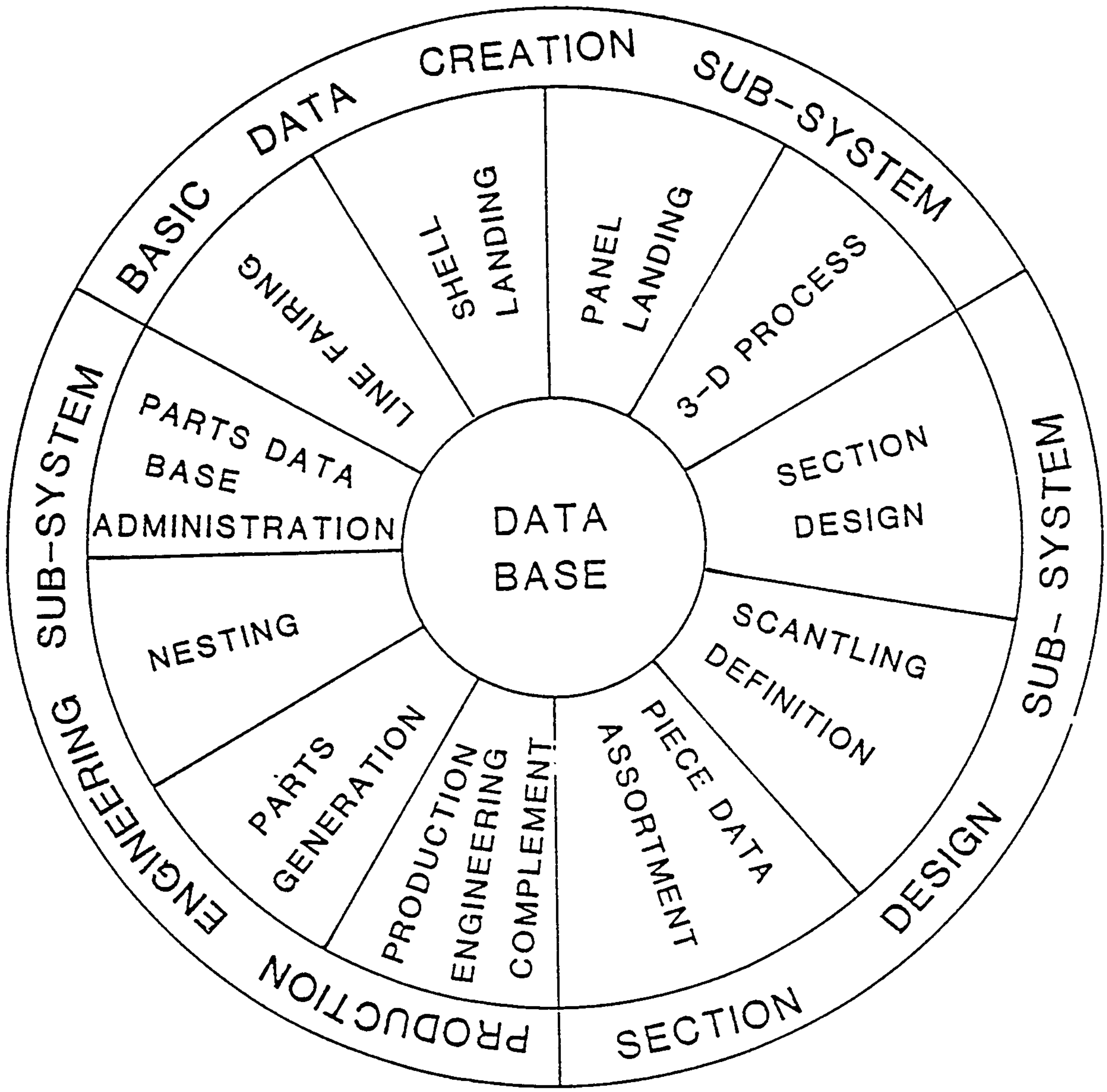


FIGURE 1-20

COMPONENTS OF IHICS

SUB-SYSTEM	MODULE	- Component Programs	OUTPUTS
BASIC DATA CREATION	FAIRING	- Lines Fairing Program	*Geometry Data Base, Panel Data Base, Scantling Data Base *Complete Drawing of any Desired Portion of Lines Drawing *Book of Mold Loft Offsets *Structural Body Plan (1/10, 1/50) *Shell Expansion Plan *Panel Plan (Deck, Bulkhead, Flat, etc.)
	SHELL LANDING	- Seam/Butt Landing Program - Longitudinals Landing Program - Scantling Definition Program	
	PANEL LANDING	- Seam/Butt Landing Program - Longitudinal Landing Program - Scantling Definition Program	
	3-D PROCESS	- Panel Definition Program - Compartment Definition Program - Cut Plane Program - Panel Composition	
SECTION DESIGN	SECTION DESIGN	- Web Figure Definition - Stiffener & Joint Arrangement on Web	*Section Plan (1/10, 1/50) *Piece Control Data List - Piece List for each assembly unit - Includes piece name, quantity , scantling, weight, piece drawing format, fabrication process and other production control data - Facilities data correction
	SCANTLING DESIGN	- Web/Face Plate Scantling Definition - Stiffener Scantling	
	SCANTLING DEFINITION	- Web/Face Plate Scantling Definition - Stiffener Scantling	
	PIECE DATA ASSORTMENT	- Piece Data Assortment Program	
PRODUCTION ENGINEERING	EDITING PROGRAM	- Part Program Generator - Plate Edge Modifier Program	*Piece Drawing (including Tabular Format) *Numerical Control Data/Tape *Piece List for each Stage of Production *Template for Bending (Shell Plate and Longitudinal Frame) *Unit Marking Data for Shell *Jig Heights for Curved Shell Unit Assembly
	PART GENERATION	- Shell Plate Development and Assembling Data Calculation (SHELL) - Longitudinal/Transverse Frame Development (LODACS) - Internal Structure Development (Line System)	
	NESTING PROGRAM	- Manual Nesting Program - Interactive Nesting Program by CADS - Post Processor for Numerical Control Machines	
	PART DATA BASE ADMINISTRATION	- Part Data Base Handler - Piece List Editing Program for: *Fabrication *Subassembly *Assembly *Erection	

TABLE T1-4

COMPONENTS OF IHICS

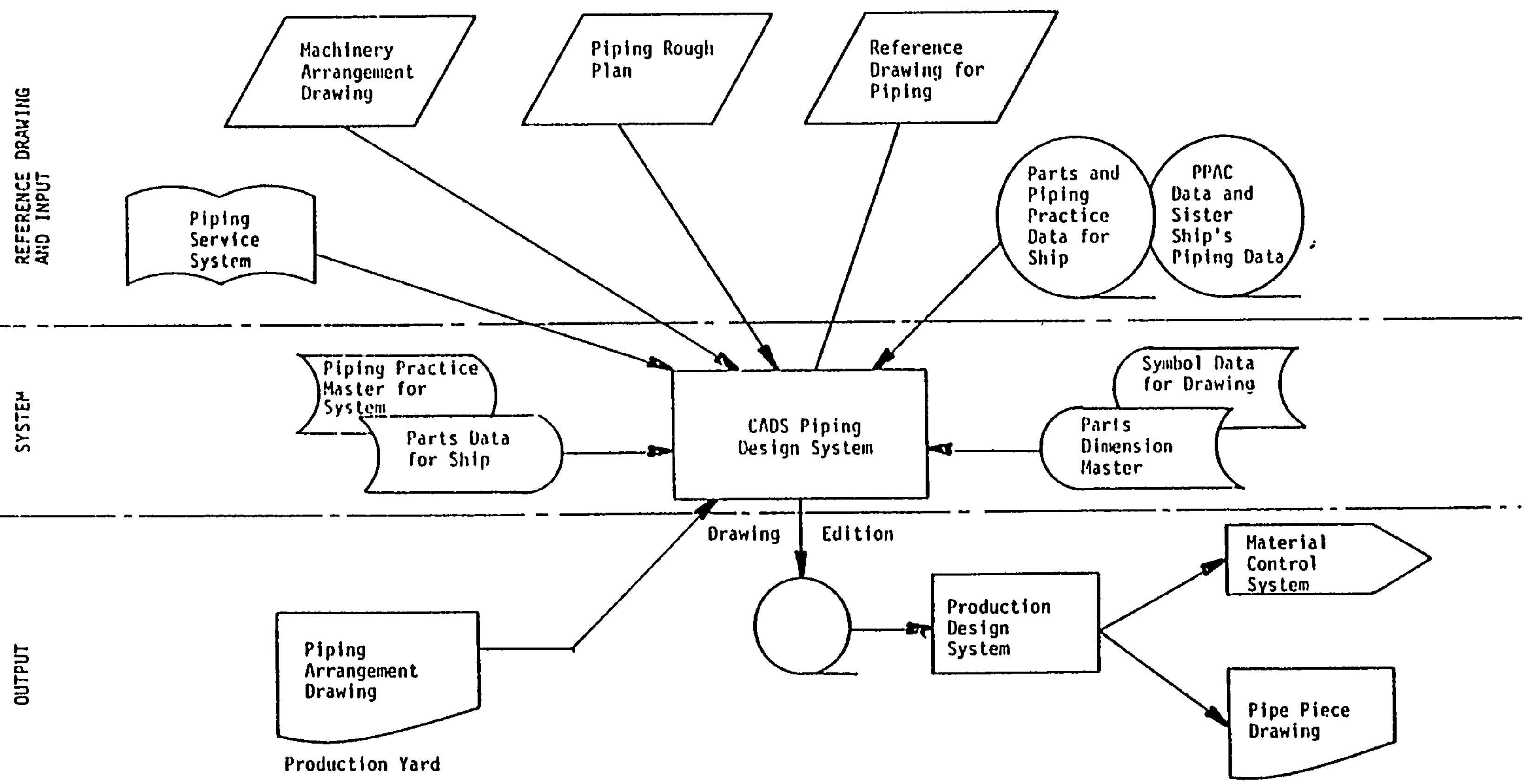


FIGURE 1-21

CADS OPERATION

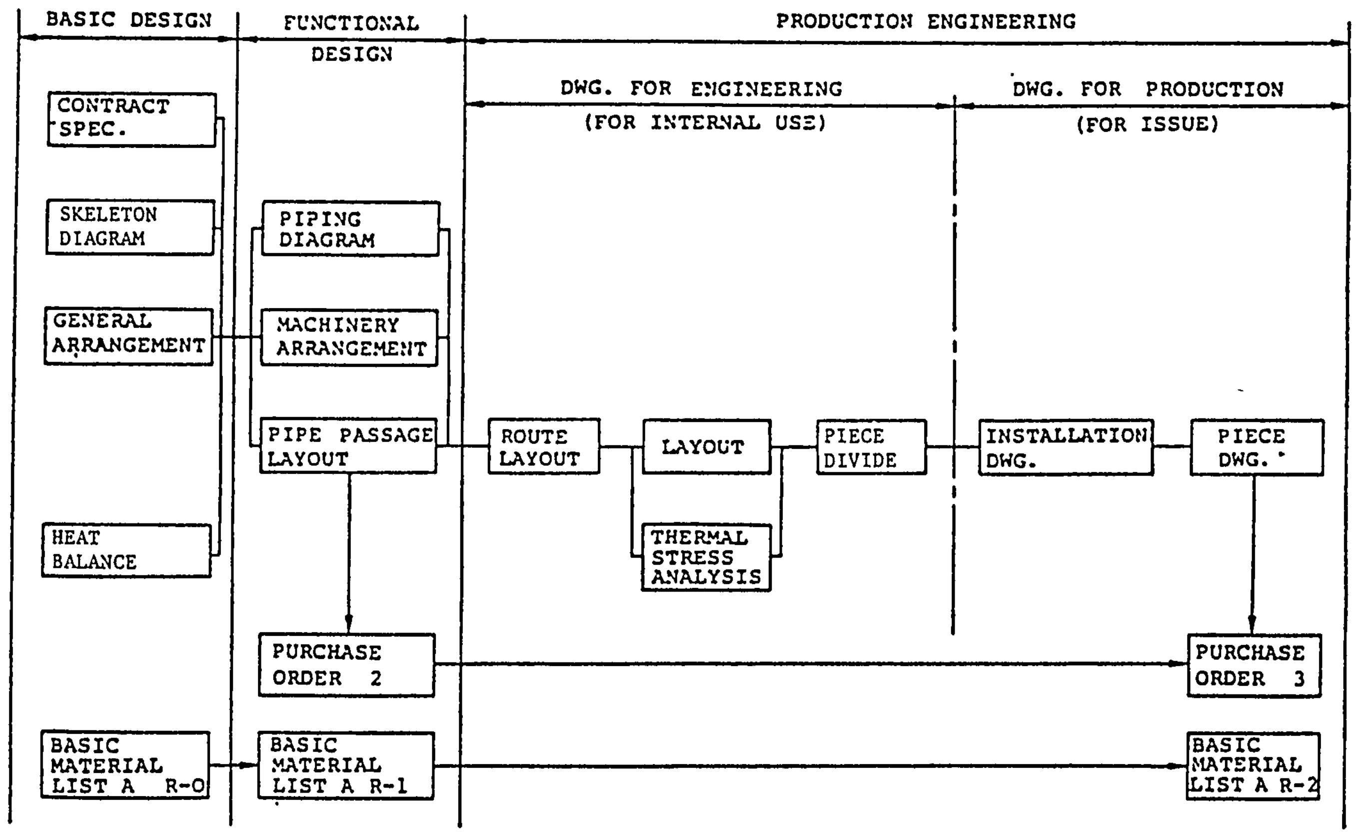


FIGURE 1-22

PROCESS OF PIPING DESIGN

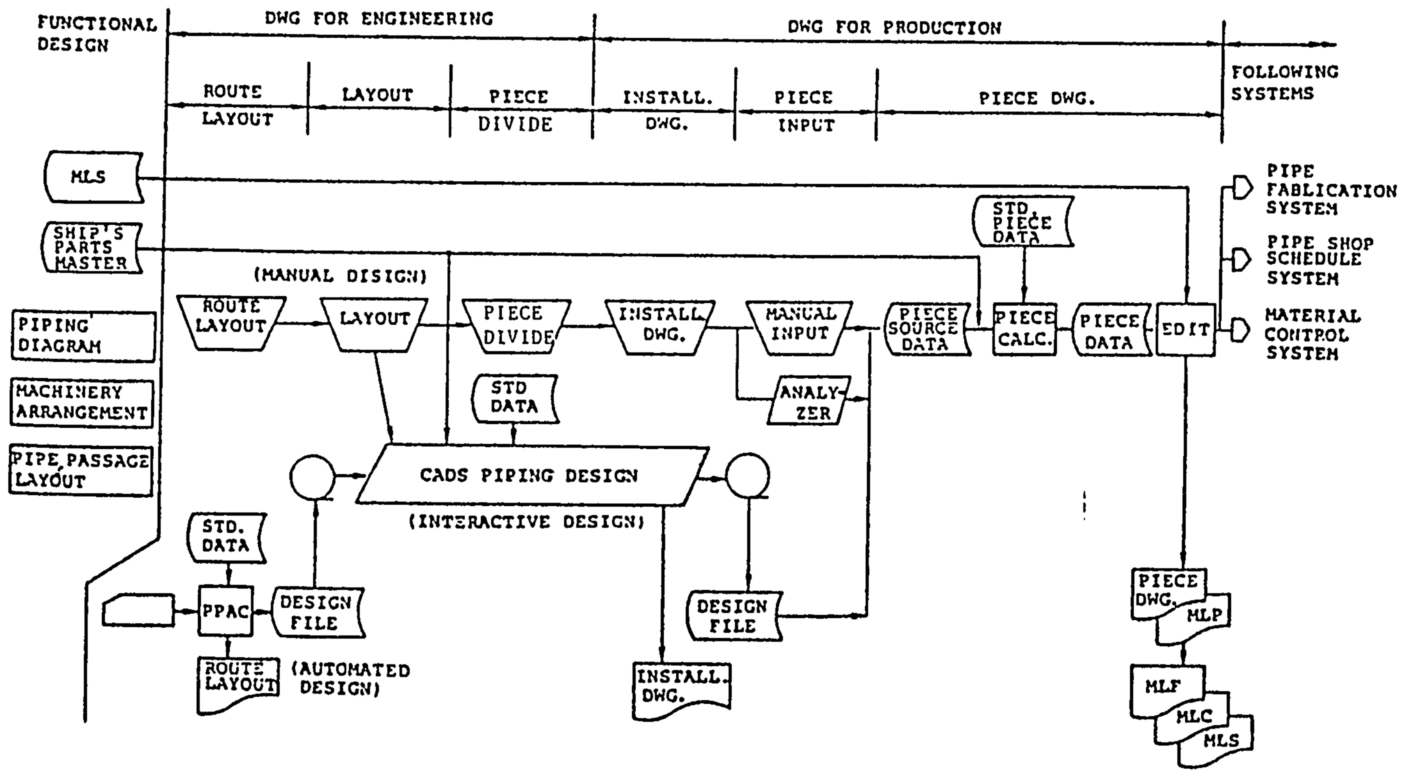


FIGURE 1-23

PIPING PRODUCTION ENGINEERING SYSTEM (ENG. RM) section view. Definition of piping runs is accomplished by indicating start and end points and bend points. Optional section drawings are available as outputs to show intersections of pipe with other structures such as tanks and bulkheads. Clearance between pipes is calculated automatically.

Other functions and characteristics of the CADS system are the setting of pipe fittings on a piping run, checking pipe piece dimensions based on fabrication standards, design of pipe support pieces, and providing data for the pipe piece fabrication system and the material control system.

NUMERICAL CONTROL STEEL FABRICATION

The design work for the hull involves the preparation of a rough structural drawing and a shell plate expansion drawing based on a typical midship section plan and a lines plan for a given vessel. Following this, detailed structural calculations are conducted and a detailed structural drawing is prepared. During these design processes, the data base is continually added to and updated. The result of this building up of the data base is a structural drawing produced by computer directed automatic drafting machines, plotters, and other graphic displays.

The preparation of structural drawings by computer points out the fact that the shapes of the various pieces are dealt with numerically. As part of the data base, these numerical data are directly tied in with the N/C (numerical control) marking and cutting equipment. The main result of this is omission of traditional mold loft practices with more automation of the production system.

At IHI, automation of many fabrication processes has led to more accurate and rapid fabrication of steel parts as well as creating more simplified jobs for the workers.

GAS CUTTING AT IHI

The philosophy and policies which affect numerical control steel fabrication in Japan's shipyards have evolved as a result of certain conditions prevalent in the Japanese shipbuilding industry. The abundance of highly skilled manpower, industry standards and highly developed facilities, among other conditions, have enabled the IHI yards to utilize N/C methods of fabrication without relying on them to perform jobs better suited to other types of equipment and methods.

IHI's alternative to old methods of mold lofting is the 1/10 scaled body plan lofting method. Large table automatic drafting machines provide high precision scaled drawings. These drawings are used for various fabrication methods including Electro Photo Marking and final checking before N/C burning. Full scale drawings of small parts such as collar plates and brackets are used as templates and to direct optical tracer burning equipment.

IHI PLATE MARKING TECHNIQUES

At IHI shipyards, plate marking is accomplished by several different processes all of which rely on N/C generated data. Selection of the marking method is made according to whether the marking will be done on a single plate or a panel that is composed of more than one plate having already been welded together.

In the case of panels, marking is done after welding to allow for neat cutting (to exact dimensions) of the panel. Steel tapes are prepared in the mold loft from tabular data and stored until required for manual marking.

For marking single plates, two main methods are applied, N/C plate marking and Electro Photo Marking (EPM). Selection of the method of marking is made with regard to leveling the workload of the yard's marking facilities and with consideration for smooth work flow.

A blend of optics and electronics, EPM is a rapid method of marking that can work a raw plate in about eight minutes. In a special dark room, the raw plate is positioned on rollers beneath a light projector that is equipped with a precision lens designed to enlarge a 1/10 scale image to full scale on the plate below.

The image that is projected is made of various 1/10 scale piece drawings produced on clear film by automatic drafting machines. These small drawings are nested on a large piece of clear film which is a 1/10 scale representation of the plate that is to be marked. All necessary material marks are manually added to this nesting drawing before it is placed in the projector so that when the EPM process is completed, all pieces will be completely marked.

Phototoner, a light sensitive powder charged with static electricity, is spread over the plate. The nested 1/10 scale drawing is then projected at full scale onto the plate. This step in the process causes the projected image to adhere to the plate. The precision of the printed pattern is accurate enough for the fabrication of hull pieces.

Numerical control plate marking is accomplished by burning zinc or plastic powder onto a plate to form a continuous 1/16" wide line. A

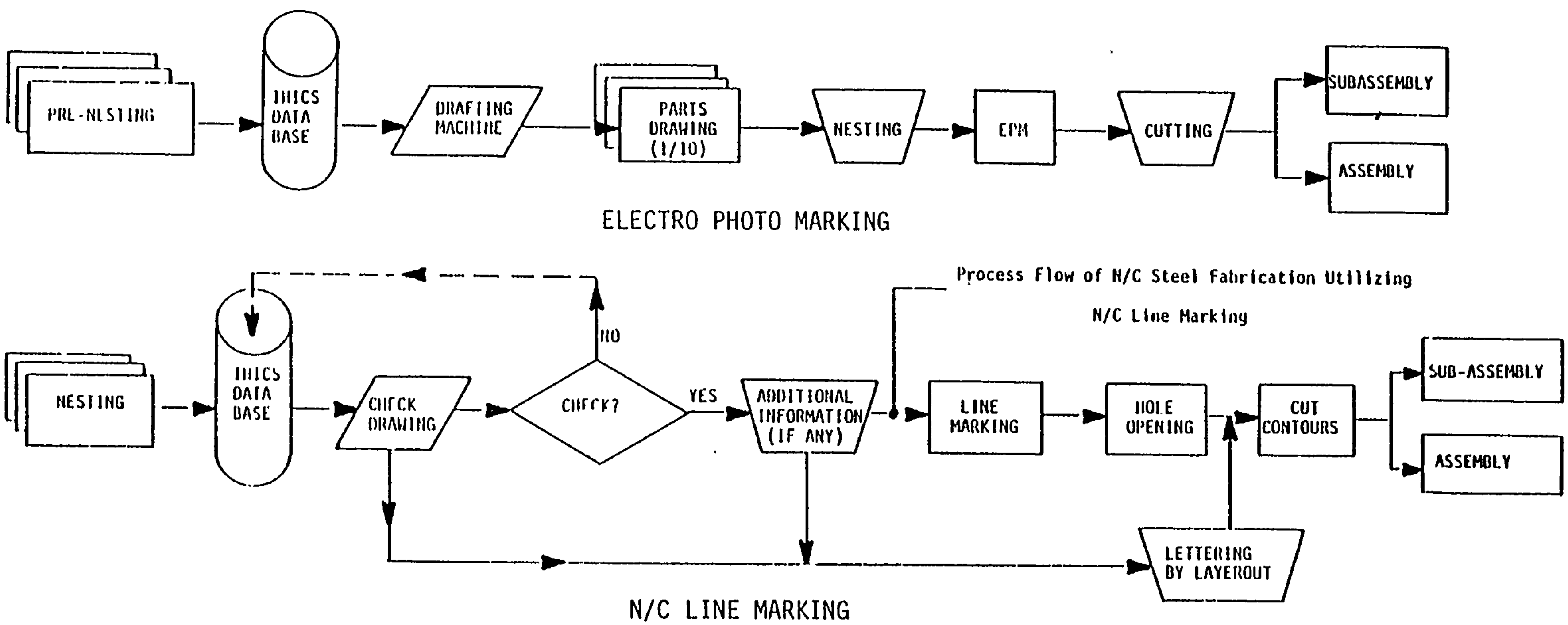


FIGURE 1-24

PROCESS FLOW OF N/C STEEL FABRICATION UTILIZING ELECTRO PHOTO MARKING AND N/C LINE MARKING special burning torch equipped with a hopper/dispenser applies the powder to the plate just ahead of the moving torch. This method of line marking is capable of laying down a continuous line at the rate of forty feet per minute.

LIVINGSTON SYSTEM AND APPLICATION OF IHI TECHNOLOGY

APPLICATIONS OF IHI TECHNOLOGY

During the course of the Technology Transfer Program, Livingston has studied the IHI design and engineering systems and practices. The various studies entailed detailed analysis and comparisons which in most cases led to decisions for implementation of the IHI technology or methodology with modification if necessary, or to reject it after cost trade-off studies were applied.

In some cases, implementation of IHI technology in areas of the shipyard other than design and engineering has brought about the need to change certain design and engineering practices accordingly.

Computer-aided Ship Design

In the area of computer-aided ship design, the IHI system and the SPADES system which is in use at Livingston were compared. Detailed documentation of both systems facilitated this comparison.

It was determined that both systems were relatively equal and there would be no need to change from SPADES to the IHI system. At that point the study concentrated on determining if full benefit from SPADES was being realized. All available SPADES modules were studied including those not in use at Livingston. A detailed comparison table of SPADES and the IHI system is provided in Appendix J of this report.

The conclusion to this study determined that both systems are very good shipbuilding tools, and while the IHI system is fully utilized to the best advantage of the IHI shipbuilding complex, SPADES at Livingston is somewhat limited by lack of implementation and facilities. It was determined, however, that SPADES may be better suited to Livingston's purposes and methods. For example, those SPADES modules that actually duplicate the old style lofting were better for Livingston because the input coding is easier and the data base is referenced by all of the SPADES modules, whereas in the IHI system some modules are of the "stand alone" type and require additional inputs.

Thus it was decided that implementation of the IHI system was not necessary and that as Livingston's requirements for computer-aided design software increased, SPADES could provide what is necessary.

Numerical Control Steel Fabrication

Some changes in Livingston's steel production methodology changed as a result of IHI's recommendations. In the area of bending and shaping steel plates for the shaped zones of the hull the IHI methodology for cold bending followed by flame bending (or line heating) was implemented. This created new demands upon the mold loft for providing special sight line templates necessary for this process. Of course, flame bending is only one step in the overall method of curved unit assembly used extensively at IHI. When this method of assembling large curved units on adjustable pin jigs was adopted still more demands were placed on the loft. In these cases, the SPADES system already provided enough data for preparing the necessary templates and for setting the heights of the pins of the adjustable jigs. It was only a matter of utilizing what was available.

In other areas of numerical control steel fabrication some deficiencies at Livingston were identified after comparison to the IHI methods and facilities. Because of various conditions present at Livingston, and also common to other U.S. shipyards, almost all lofting work was performed in the N/C loft and almost all plate was marked and burned by the N/C burning and marking machine. As an alternative to this practice of burning everything by N/C methods, another method of automatic burning has been installed in the form of a 1:1 optical-tracer burner director. This has lessened the load on the N/C burner considerably. A high speed parallel burner has also been installed for burning flat, straight plates.

Various other recommendations from IHI have also been implemented such as leveling of the workloads between the various processes for fabrication and rearrangement of shops and facilities.

Zone Fitting and Composite Drawings

The IHI Methodology for outfitting a vessel involves Zone Outfitting and Palletization. These concepts provide benefits to the total system in terms of manhour savings, material management and personnel attitudes. However, more engineering time is required to support them.

Zone outfitting and the pre-outfitting of hull units prior to erection may do more than any other single aspect of IHI technology toward optimizing timely and profitable ship production. Therefore, whatever design and engineering methods, systems and practices are required for their implementation must be seriously considered.

Transformation to zone orientation begins with a hull unit arrangement or breakdown. The next step is preparation of composite drawings for outfitting according to the established three dimensional outfitting zones. These composites show zone boundaries and include all systems within that zone. Interferences between systems are recognized and eliminated during the preparation of these composite drawings.

Work Instruction Drawings and Material Lists

Further processing of the design is necessary for producing the working drawings to be used by Production. These drawings identify the area of the outfitting zone and the stage of the production sequence at which the work will be performed. For the hull, designations are made on assembly, sub-assembly and cutting plans. For outfitting, designations are made on work instruction drawings, each of which is developed with its own material lists for the on-board, on-unit or sub-assembly stages. This hierarchical sub-division continues by zone/area/stage with the preparation of the detail design drawings for pipe pieces and components other than pipe and their respective material lists.

It is in the manner described above that the engineering and planning process continues until each zone is broken down to a minimum level. The material lists also facilitate palletization, the IHI method of material management. The material lists for a specific zone/area/stage are used to gather the material and place the material in a physical pallet for shipment to the site at which that material will be installed. Such an organized material system facilitates rapid performance of outfitting tasks, whether they take place at the sub-assembly, on-unit or on-board stage.

Automated Scaled Body Plan of Mold Lofting

From the early stages of the Technology Transfer Program IHI has recommended implementation of scaled body plan lofting. This system involves the installation of a large table automatic drafting machine in the mold loft and a drum type plotter/drafter in the hull section of the engineering department.

IHI uses the large drafting machine for making templates for the cutting, shaping and verification of parts. The high accuracy and speed of the machine makes it possible to use its graphic output for directing optical tracer type burning equipment and for high efficiency electro photo marking equipment.

In the engineering department, the drum plotter calls upon the established data base for a ship and rapidly produces drawings that can be manually sectioned and detailed and actually used as working drawings.

The addition of both of these machines could result in significant manpower savings in the mold loft and the engineering department's drafting sections.

Additional Future Implementation

In addition to those specific areas of future implementation identified in the preceding paragraphs, other methods, systems and practices may become necessary at Livingston. As the production methodologies evolve and change, so must the practices of those functions that support this production. Design and engineering must provide what the total system requires and at the same time must be provided with the support and lead-time necessary to successfully perform those functions.